Advances in Intelligent Systems and Computing 524

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Information Systems Architecture and Technology: Proceedings of 37th International Conference on Information Systems Architecture and Technology—ISAT 2016—Part IV

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Preface

This four-volume set of books contains the proceedings of the 37th International Conference on Information Systems Architecture and Technology, or ISAT 2016 for short, held during September 18–20, 2016 in Karpacz, Poland. The conference was organized by the Department of Management Systems and the Department of Computer Science, Wrocław University of Science and Technology, Poland.

The International Conference on Information Systems Architecture and Technology has been organized by the Wrocław University of Science and Technology since 1970s. The purpose of the ISAT conference is to discuss a state of the art of the information systems concepts and applications as well as the architectures and technologies supporting modern information systems. Contemporary organizations seem to be knowledge-based organizations and in connection with that information becomes the most important resource. Knowledge management is the process through which organizations generate value from their intellectual and knowledge-based assets. It is a management philosophy, which combines good practice in purposeful information management with a culture of organizational learning, in order to improve business performance. The computers are able to collect and select the information can make some statistics, and so on, but decisions have to make managers basing on their experience and taking into consideration computer support. An improvement of decision-making process is possible to be assured by analytical process supporting. Applying some analytical techniques, such as computer simulation, expert systems, genetic algorithms, can improve quality of managerial information.

One of the conference's aims is also to consider an impact of the knowledge, information, computing, and the communication managing technologies of the organization functionality scope as well as the enterprise information systems design, implementation and maintenance processes taking into the account various methodological, technological, and technical aspects. It is also devoted to the information systems concepts and applications supporting exchange of goods and services by using different business models and exploiting opportunities offered by Internet-based electronic business and commerce solutions.

ISAT is a forum for specialized disciplinary research, as well as on interdisciplinary studies that aims to present original contributions and to discuss different subjects of today's information systems planning, designing, development, and implementation. The event is addressed to the scientific community, people involved in variety of topics related to information, management, computer and communication systems, and to people involved in the development of business information systems and business computer applications.

This year, we received more than 110 papers form about 10 countries. Each paper was reviewed by at least two members of Program Committee or independent reviewers. Only 86 best papers were selected for oral presentation and publication in the 37th International Conference on Information Systems Architecture and Technology proceedings.

The book is divided into four volumes which splits papers into areas: Managing Complex Planning Environments, Systems Analysis and Modeling, Modeling of financial and Investment decisions, Risk Management, Project Management, Logistics and Market, Artificial Intelligence, Knowledge Based Management, Web Systems, Computer Networks and Distributed Computing, High Performance Computing, Cloud Computing, Multi-agent Systems, Internet of Things, Mobile Systems, Service Oriented Architecture Systems, Knowledge Discovery and Data Mining, Quality of Service, E-Business Systems.

We would like to thank the Program Committee and external reviewers, who were essential for reviewing the papers and ensuring a high standard of the ISAT 2016 Conference and its proceedings. We thank the authors, presenters, and participants of ISAT 2016, and without them the conference would not have taken place. Finally, we thank the organizing team for their efforts during this and previous years which have led to a successful conclusion of the conference.

Wrocław, Poland
September 2016

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Part I
Risk Modeling in Decision Making Process

Selected Methods of Risk Modelling in Management Process

Zofia Wilimowska, Sebastian Klaudiusz Tomczak and Marek Wilimowski

Abstract A company's value increasing is the main goal of the firm activity that creates opportunities for long term functioning and its development. The goal realization makes the investors seeing the company better and the company can find the capital easer. Uncertainty and the risk that is associated with business activity require a special instrument supporting managerial decision that creates firm's value. In the paper some selected methods of risk modelling are presented; stochastic method, fuzzy method, fractal method and discrete method are considered.

Keywords Bankruptcy prediction models · Risk · Cluster analysis

1 Introduction

Risk is a result of uncertainty of future values quantity causing business decisions effectiveness. Uncertainty is a feature of the reality that represents impossibility of describing future events exactly. Its sources are objective factors effecting by situation variability and complexity and subjective causing by personal intellectual processes.

J. Pfeffer said that a risk … is a combination of gambling and is measured by probability; uncertainty is measured by the level of faith. The risk is state of the world; uncertainty is a state of mind. And Pfeffer and Salancik say, that …it is the fact of the organization's dependence on the environment that makes the external

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constraint and control of organizational behavior both possible and almost inevitable" and that groups that control the most vital resources or can reduce the uncertainty of other organizations have the most power [5].

The risk is an attribute of any managerial decision. It results from uncertainty about the future value of magnitude affecting the efficiency of investment. It occurs always. Any decision in the enterprise should be preceded by an analysis of risk.

S. Lumby states [4]: However, when we look at the research work that is currently being undertaken, we find that a very substantial proportion of it is concerned with the presence of risk in decision making, because it is our lack of understanding about risk—its nature, measurement and investor's attitude towards it—that causes the greater number of problems and unanswered questions.

Researchers continuously are looking for quantity risk measures but often consider quality factors also. Psychological research of the decision-making process shows that risk level evaluation depends on quantity and quality dimensions. Managers' risk evaluation depends on their personal characteristic, for example: knowledge and experience, susceptibility for emotions, having an influence on events proceeding, action voluntarily degree, stimulation need feeling, sensibility on suggestions etc., or factors that determine decision situation:

An uncertainty and a risk which are associated with business activity require a special instrument supporting managerial decision that creates firm's value. Models of financial effectiveness analysis based on classical theories do not good enough follow the environmental changes that create the risk associated with managers' decisions. Classical models of the risk are based on assumption that return ratios are random or stochastic variables. There is possible non-linear presentation of models used to control business risk in company valuation process:

- Fuzzy models,
- Chaos theory models
- Catastrophic theory models,
- Cluster analysis models,
- Fractal models,
- Agent models.

Risk is understood, as a possibility that actual cash flows will be less than forecasted cash flows–actual rate of return will be less than expected required return because variability and unpredictability of the cash flow levels CFi in future time periods, (Fig. 1). If required level of cash flow is a linear function of time CF(t) (then the risk connected with variability of cash flow is zero, and growing level of cash flow increases investment profitability), then for investment A variability of CFA(t) is greater, so the risk is greater. For investment B cash flow CFB(t) is the least stable–it causes the greatest risk.

Time is the important factor of managerial risk, for example an investment risk. The longer forecasting period the less certainty that actual cash flows (returns) will be equal forecasted cash flows (returns) that means–higher risk, (Fig. 2).

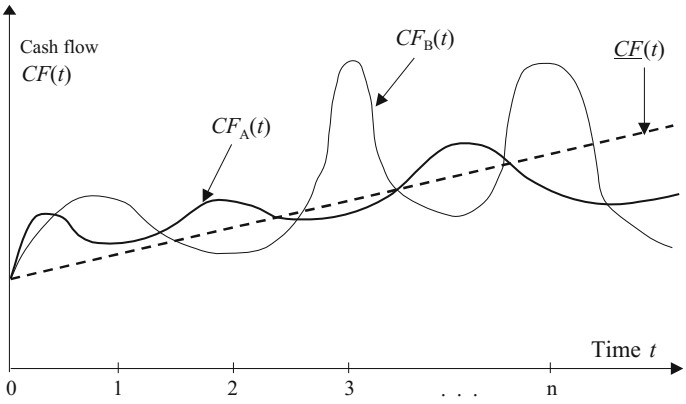

Fig. 1 Variability of cash flows for A and B firms. *Source* [9]

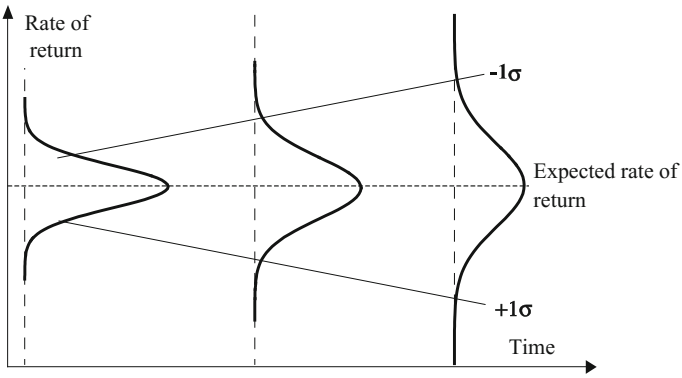

Fig. 2 Risk changing with the time

It not mean that in future periods cash flows will be less certain, it means that the forecasting is less certain only. So, from the investor's point of view, the investment is more risky.

The researchers are looking for methods that let them tie the risk presence and time. Stability of the firm's performance depends on stability of many factors that influence profit stability.

The factors that determine company's value, Fig. 3, which exists in dynamically changing environment and influencing the forecasted cash flow level and discounted rate are not deterministic. They follow the unpredicted environment changes and internal changes of the company. So the factors should have nondeterministic character in valuation process.

For example, the DCF method of company's valuation is based on forecasted cash flows discounted by WACC rate. The forecasting should be preceded by

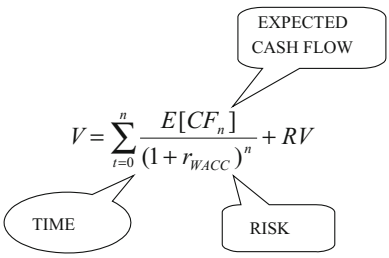

Fig. 3 The idea of the firm's value calculation. *Source* [9]

determining the value factors, for example: sales and profit growth ratios, efficiency ratios, Debt/Equity ratios and liquidity ratios, assets quality ratios, market ratios and so on.

2 Risk Measures

The dynamic changes in the economic environment affect change and unpredictability of variables determining company's value need proper risk measures. Dynamic factor of risk can be described in stochastic process terms.

2.1 Stochastic Measure

It is assumed that cash flow CF(t) is a stochastic processes. Then, expected value

$$\mathrm{E}[\mathrm{CF}_{(t)}] = \int_{-\infty}^{\infty} f(CF) CF dCF, \tag{1}$$

and the risk measured by standard deviation

$$\sigma_{(t)} = \sqrt{\int_{-\infty}^{\infty} f_t(CF)(CF(t) - E[CF(t)]^2 dR}, \tag{2}$$

are functions of the parameter t.

Probabilistic approach requires knowledge of the probability of all events. Where this is not possible, it is assumed that all events are equally probable (principle of insufficient reason Laplace). This rule says that if there is no a priori knowledge, all unknown values of the parameter should be considered equally probable. If it is not possible to determine the exact measure in the form of precise level of probability it seems reasonable to consider the probability measure in the form of a range or a set. From the definition of probability measure in the form of a range or a set follow important conclusions:

- There is no need to determine the exact measure of the probability in situation where it is unrealistic and impossible to implement.
- Do not impose the rules of Laplace insufficient, which means that you can use statements about the possibility of cumulative occurrence of events without relating it to the assumptions of the probability of single events.
- Measures must not add up to one. If this happens, then we have to deal with the traditional presentation of probability. The sum less than 1 (subadditive case) is the incompatibility between multiple sources of information. The sum greater than 1 (superadditive case) means acquisition the same information from multiple sources.

Because there is no single type of uncertainty, and probability theory can not be used to solve any problem including the uncertainty, many theories were created for recognition and modelling the uncertainty.

The disadvantages associated with the use of probability in economic issues caused the search for alternative solutions.

2.2 Fuzzy Models

Fuzzy numbers are one way of modeling incomplete knowledge of man and can be used in making decisions under uncertainty. Fuzzy numbers play a similar role as the probabilistic approach. Fuzzy numbers can be used to represent the unknown values yet. These values are for example the number of items of goods, which the company will sold in the next year, and in consequence the level of CF will be a fuzzy number. Their value will be known in the future, but appropriate decisions to be taken at this time, on the basis of incomplete knowledge.

The company value can be evaluated by:

$$\tilde{V} = \sum_{t=1}^{t=\infty} \frac{\widetilde{CF_t}}{(1 + r_{WACC})^t}, \tag{3}$$

where:

$\tilde{V}$ - fuzzy company value,

$\widetilde{CF_t}$ - fuzzy cash flow value in t period of time

r_{WACC} - weighted average cost of capital

Another approach to the problem of measuring uncertainty presents A. Jøsang [1] in logic uncertain probabilities. In a standard logic assumes the value: true or false. But no one is able to determine with absolute certainty that the assumptions are true or false. In addition, if it is estimated that the assumption is true, then it will always be a subjective judgment and never will represent the general opinion. This indicates some deficiencies in the way of the world perception that proposes a standard logic. It is primarily intended for the world idealized and not for the real world–in particular the business world, for example to estimate the

cost-effectiveness of managerial decision. Subjective logic is commonly referred to as the logic which is based on subjective beliefs, propositions about the world. Uses the term "opinion" to select a subjective character of expression proclaimed. Opinion may be considered as a measure of the probability of containing secondary uncertainty. Uncertainty determines the uncertainty associated with the term probability. Although it is assumed that uncertainty is unmeasurable here uncertainty function will accept certain values resulting from the subjective logic.

2.3 Fractal Models

The fractal dimension was defined by Mandelbrot during the study coastline of Great Britain Thanks to this research, he noted that the coastline is not an object Euclidean, so its dimension can not be described by an integer of 2 [2]. The entire coastline was covered with N circles having the same radius–r. These measurements were repeated reducing and increasing radius. It turned out that every time it was obtained the following equivalence relation:

$$N(2 * r)^D = 1, \tag{4}$$

where: N—numer of circles, r—radius of circles, D—fractal dimension.

So the fractal dimension is:

$$D = \frac{logN}{\log(\frac{1}{2r})}. \tag{5}$$

The more the object will be frayed and ragged the more the fractal dimension approach will be to the value of 2.

Hurst exponent, as a statistical measure used for deterministic fractal, dependent only on the value of the correlation coefficient C between the pair tested parameters, which can be stored in the form [3]:

$$C = 2^{(2H-1)} - 1, \tag{6}$$

where: C—correlation coefficient, H –Hurst exponent.

So the fractal dimension is:

$$H = \frac{1}{2}\left(1 + \frac{logC}{log2}\right). \tag{7}$$

The possible value of Hurst exponent can be between 0 and 1.

- When the value H is below 0.5 one can say that the analysed signal is anti-persistent, which mean that there is a big probability that in next step will be

opposite to the current step. It is worth mentioning here that they discussed the size takes a value closer to zero the more "jagged" signal (more unpredictable, more risky).

- For a value H equal to 0.5 the signal is random and one can say that it's more like a Brownian motion. T

The last interval for H is value higher then 0.5. In this interval signal is persistent, which mean there is bigger probability that in the next step signal will behave like current step (trend will not be reversed). This means that the greater the value of H assumes the smoother the signal being analyzed (less unpredictable, less risky).

DMA method, as one of the few, is used for random fractals, which is difficult to define basic parameters. The reason for this is to prevent uncontrolled change determination endlessly circles of a given radius that bridge the entire test object. The main objective of the DMA method is that the signal fluctuations scaled accordingly with increasing scaling exponent (strongly dependent fractal dimension) [2].

2.4 Discrete Measures

The company risk (risk of bankruptcy for example) evaluation problem can be defined as follows [10]

> to classify a firm to one of M risk classes–1, 2,…, M using some factors describing it.

Depending on type and quantity of input information, two tasks are considered:

1. number of risk classes is known,
2. number of risk classes is unknown.

The tasks can be resolved using cluster analysis and pattern recognition theory, respectively.

In the risk classification task, points of the feature space are firms described in vectors of features terms. Process of discrete financial risk measuring shows Fig. 4.

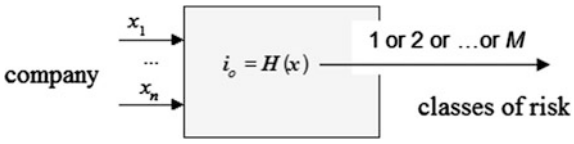

Fig. 4 Scheme of risk classification

In the company risk measuring process, the elements of vector xT could be for example financial ratios. The main problem of right classification is to find the proper function of H(x) transforming the feature vector in a particular class i0. There are many researches of pattern recognition and classification theory. The methods depend on type of information that is known before.

Let's assume that objects in each M classes are random variables and p(x/i) i = 1,…, M are their a'priori conditional probability functions. Let's assume that pi, i = 1,…, M are a'priori probabilities of class i respectively. If probability distributions p(x/i) and pi, i = 1,…, M exist and are known, than full probabilistic information about objects and classes is known.

Using statistical theory of decision making there is possible loss functions defining λ(i/j) i, j = 1,…, M, which represent losses of incorrect classifying of object i to wrong class j.

Let's describe p(j/x) as a'posteriori probability that x belongs to class j. Then

$$L_X(i) = \sum_{j=1}^{M} \lambda(i/j)p(j/x) \tag{8}$$

is an average conditional loss.

Object belongs to class i0, which minimizing value $L_X(i)$. The scheme of the algorithm is:

1. Describe object x.
2. Count $\underset{i=1,2,\ldots,M}{\wedge} L_x(i)$.
3. Make decision that x belongs to class $i_o \in \{1, 2,\ldots, M\}$, for which

$$L_X(i) = \min_{i=1,\ldots,M} L_X(i). \tag{9}$$

A very simple algorithm can be used if the loss function is „0-1" function.

Let define for i, j = 1, …, M

$$\lambda(i/j) = \begin{cases} 0, i = j \\ 1, i \neq j \end{cases} \tag{10}$$

then

$$l_X(i) = \sum_{\substack{j=1 \\ j \neq 1}}^{M} p\left(\frac{X}{j}\right)p_j = p(x) - p(x/i)p_i \tag{11}$$

In this situation the object x is classified to class $i_o \in \{1, 2, \ldots, M\}$, for which

$$p(x/i_o)p_{i_o} = \max_{i-1,\ldots,M} p(x/i)p_i \tag{12}$$

3 Research—Risk Evaluation for Polish Industry Companies

In the research 200 companies from the manufacturing sector were analyzed. Half of them (100 companies) are companies that have declared bankruptcy and/or are in the process of liquidation. The second half (100 companies), are companies characterized by a relatively good financial condition (based on ratio analysis).

First, these reports of companies were selected, which has been available (at least three) in the period from one to five years before the bankruptcy. The source of these financial reports are EMIS database. One year before bankruptcy was access to 100 reports, two years before bankruptcy was access to 100, three years before bankruptcy was access to 100, four years before bankruptcy was access to 75, and five years before bankruptcy was access to 43.

A total of 100 bankrupt companies were covered by the analysis. Then, the equivalents of insolvent companies were selected which still operate and have not been subject to any bankruptcy procedures (this has been checked in the National Court Register). In the selection of these companies, were the following criteria: industry, the reporting period, good financial standing and size of the company.

The sample is homogeneous, because it consists of two types of commercial companies: the limited liability companies (75 %) and the joint-stock companies (25 %).

3.1 Number of Classes Determining

The objective of the research is to determine the number of classes characterizing the financial condition of enterprises base on 4 ratios: Current liquidity ratio, Equity to assets ratio, Income dynamics ratio, Payables turnover ratio,[1]

$$X1 = \frac{(current\ assets)}{(short - term\ liabilities)}; \tag{13}$$

$$X2 = \frac{(equity)}{(total\ assets)}; \tag{14}$$

$$X3 = \frac{(net\ sale(n))}{(net\ sale(n-1))}; \tag{15}$$

$$X4 = \frac{((short - term\ liabilities) * 365\ days)}{(net\ sale)}. \tag{16}$$

[1]Detailed information on the selection of financial indicators can be seen in: [6, 8].

For classes definition, the agglomeration method will be used. The result of this method is the tree of connections so called the dendrogram. Using the method of agglomeration researcher subjectively determine the number of classes (clusters) setting the line of intersection of the tree.

Dendrogram was constructed using the method of Ward and the Euclidean distance, which were used to determine the cluster for selected financial ratios. The values of the four financial ratios for the year before the bankruptcy of enterprises were taken into account. It should be noted that before the cluster analysis the variables were standardized in order to unify the measurement of variables. The results of the cluster analysis are shown in Fig. 5.

The line of intersection shall be set when the distance between the clusters links begins to move away. In this case, the distance between the clusters linkages begins to move away at 8. However, the cut line was not set at 5 linkages distances. Due to the very large number of clusters at this level with the simultaneous low number of objects in these clusters.

The lines of intersection was set at 16. The line crosses the five clusters. The first cluster consists of 42 companies that have a good financial condition. The second cluster is composed of 31 companies that are characterized by a sufficient financial condition. In contrast, the companies which have a frail financial condition are in the third cluster in the number of 36 companies. On the other hand, the fourth cluster consists of companies with a very bad financial condition in the number of 54 companies. The last cluster is composed of companies with a critical financial condition in the number of 7 companies. In total, there are 170 enterprises in all the clusters (some indicators were missing therefore such firms were removed from the analysis).

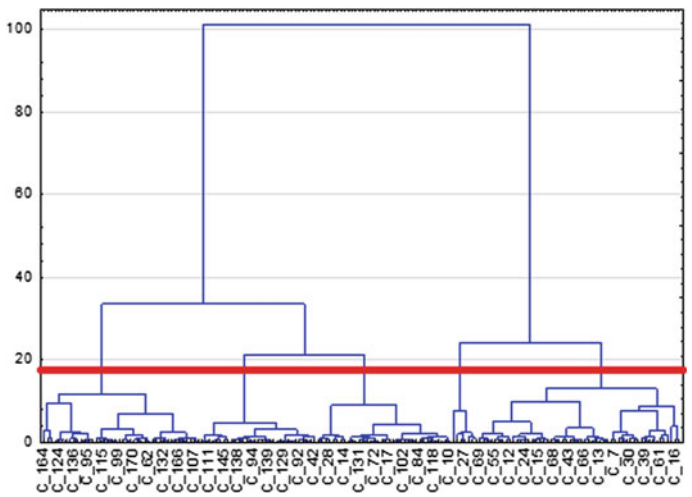

Fig. 5 Cluster analysis using the methods of agglomeration

Table 1 The calculated average values of financial indicators for each cluster

Number of cluster	Current ratio	Equity to assets ratio	Income dynamics ratio	Payables turnover ratio	Level of risk–Type of financial condition
Cluster 1	3.197	0.728	1.096	52	Very low risk–good
Cluster 2	1.875	0.576	1.315	74	Low risk–sufficient
Cluster 3	1.603	0.577	0.940	82	Average risk–frail
Cluster 4	0.837	0.125	0.904	205	High risk–very bad
Cluster 5	0.344	−0.261	0.604	566	Very high risk–critical

Next, the companies were selected, which on the basis of the analysis of the agglomeration were included in the particular cluster. After that the average values of the analyzed financial ratios of the individual companies were calculated for each cluster (Table 1).

The descriptive statistics were calculated on the grounds of average values and the standard variations of financial ratios for the particular enterprises included in a given cluster.

In the selection process, the financial ratios were tested with appropriate tests to check if the values of ratios show normal distributions. What is more, descriptive statistics which defined the financial ratios of particular classes were calculated, for each ratio, as well as the value of function density of conditional distribution was determined $f(x_i|j)$, where $i = 1, 2, 3, 4$; $j = 1, 2, 3, 4, 5$.

3.2 *Process of Classification*

A priori probabilities for 5 classes are calculated based on the percentage of announced bankruptcy of economic entities in relation to the total deleted companies from REGON register. Therefore, the a priori probability of class 1, 2, 3 is equal 0, 31 and for class 4 and class 5 also is equal 0.035.

The features—financial ratios are random variable for which:

- probability density functions are normal;
- ratios are randomly independent.

Results of Kołmogorow-Smirnow test and histogram figures of numerous lay out of tested ratios in the class were calculating by computer program STATISTICA.

The test for normal distribution of selected indicators was carried out for each year separately, keeping a division between companies with good financial condition and the bankrupt companies. A total distribution of 40 indicators had been tested (2 groups of companies, 4 indicators for 5 years).[2]

[2]Detailed information on testing the probability distribution of financial ratios can be seen in: [7].

Examples of the results of the Kolmogorov–Smirnov test for companies with bad and good standing are presented at the Fig. 6.

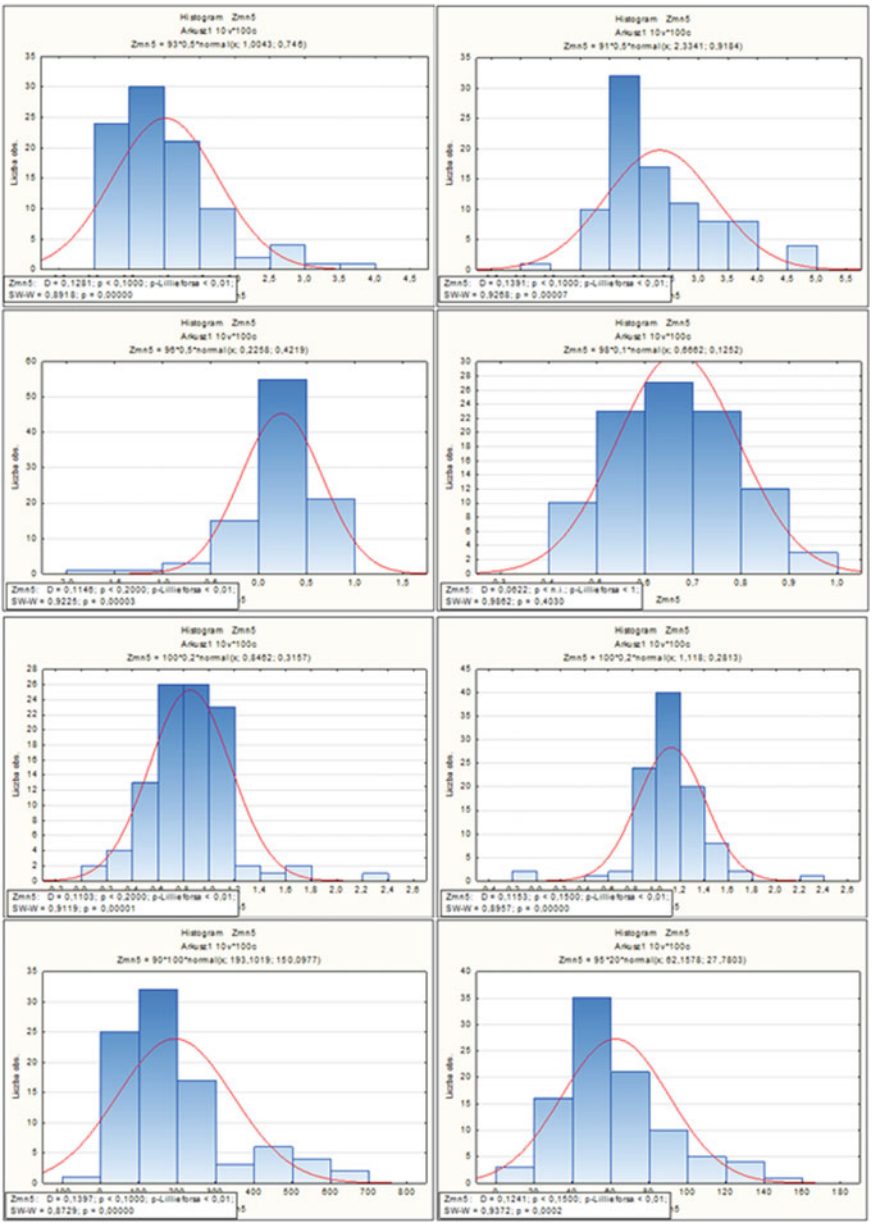

Fig. 6 Histogram of ratios X1, X2, X3, X4 for companies with bad (from *left*) and good condition (from *right*) together with the density function of probability distribution for the year before the bankruptcy of enterprises

Table 2 The descriptive statistics for each cluster

Cluster number	The statistics	Current ratio	Equity to assets	Income dynamics	Payables turnover
Cluster 1	Mean	3.197	0.728	1.096	52
	Standard deviation	0.729	0.083	0.276	21
Cluster 2	Mean	1.875	0.576	1.315	74
	Standard deviation	0.340	0.117	0.114	27
Cluster 3	Mean	1.603	0.577	0.940	82
	Standard deviation	0.351	0.114	0.166	37
Cluster 4	Mean	0.837	0.125	0.904	205
	Standard deviation	0.377	0.241	0.267	92
Cluster 5	Mean	0.344	–0.261	0.604	566
	Standard deviation	0.279	0.677	0.170	73

Application of Bayes model requires the calculation of descriptive statistics for each cluster–class (Table 2).

The descriptive statistics were calculated based on the average and standard deviation values of financial ratios listed companies included in a given cluster.

Remembering that Bayes algorithm needs a value p_j f(x/k_j) calculation for each class and choosing the maximum value of that a'posteriory probability of class, the exemplary results of classification shows Table 3.

3.3 Agent Model

Dynamic development of the IT technologies creates the possibility for using them in dynamic management process modelling.

Software agents are well known in the area of computer science. They have already been successfully applied in many fields of technology and natural sciences. The idea of agent and software agent is multidimensional and has different origin. However, from the technical point of view each software agent can be understood as an autonomous system consisting of software components (Fig. 7) that have the following features:

- it is situated in an artificial or natural world,
- it has facilities to sense its external world and to manipulate it,
- it has at least partial representation of the world,
- it is goal–directed, hence it has the ability to plan its autonomous activities.

Table 3 The examples of classification by Bayes model

Company	Real class	Result of class 1	Result of class 2	Result of class 3	Result of class 4	Result of class 5	Class
Copal	1–3	0.996	0.004	0.000	0.000	0.000	1
Androimpex	1–3	0.001	0.542	0.457	0.000	0.000	2
Druk-Pak S.A.	1–3	1.000	0.000	0.000	0.000	0.000	1
Hak Sp. z o.o.	1–3	0.122	0.000	0.878	0.000	0.000	3
Lenko S.A.	1–3	0.000	0.000	0.001	0.999	0.000	4
Hydro partner	1–3	0.001	0.091	0.907	0.000	0.000	3
….							
Jeremias	1–3	0.638	0.182	0.180	0.000	0.000	1
ASTARTA Holding N.V.	1–3	0.000	0.962	0.038	0.000	0.000	2
ADP Sp. z o.o.	4–5	0.000	0.000	0.000	1.000	0.000	4
AUPRO Sp. z o.o.	4–5	1.000	0.000	0.000	0.000	0.000	1
AZOMET Sp. z o.o.	4–5	0.000	0.000	0.000	1.000	0.000	4
B.P. Print Sp. z o.o.	4–5	0.000	0.000	0.000	1.000	0.000	4
…	4–5	0.000	0.000	0.002	0.998	0.000	4
BZPB Sp. z o. o.	4–5	0.000	0.000	0.000	0.000	1.000	5

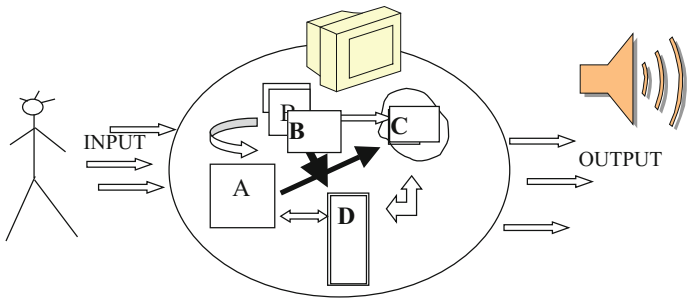

Fig. 7 Software agent

A natural social extension of this idea of an individual agent assumes that software agent can be co-operative and able to interact with other agent–like entities (including humans). Obviously, the latter ability requires a suitable language of (multiagent) communication with semantics and pragmatics that covers details of desired agent–to–agent control.

The way, in which the agent technology can be used in an implementation of value-based management, depends very much on the desired scope of its

automation, the nature of existing data (electronic or not) and the access to this data. Obviously, the first step to design software–based implementation of this methodology is to determine autonomous subsystems of company/s actions and decisions. An example of such a subsystem is built from all activities necessary to calculate CF (t), (Fig. 8). In this case a designed software agent is responsible for collecting data from data sources distributed over the computer network, pre-processing this data, setting its internal goals, and launching goal- directed actions.

In the agent model a software interface can play the role of a counterpart for the facilities to sense the external environment, models and profiles of external entities give a partial representation of the world, and general goals are defined as to monitor the state of CF(t) to stabilise profit, and to control other agents by sending relevant messages.

The main idea of using agent model in valuation process is to build simulated process of the company and controlling it. In the model presented at Fig. 8 the interface (A) collects and transforms information flowing from an environment–play a role of external World. Interface C main goal is monitoring of cash flow level and controlling the other agents by sending right commands.

Subgroup of agents is intelligent agents. G. Tecuci defines intelligent agent as a system with base of knowledge, which warns its environment, makes facts interpretation, resolves the problems, influences environmental changes and determines its activities to achieve its goals.

Agent cooperates with users or other agents but the cooperation is active–agent can make tasks modification can require giving reasons of recommendation or can refuse executions. An intelligent agent is a computer program that is able to think, that behaves in agreement with its some knowledge, intelligence and exploitation mechanisms.

Base of knowledge preserves all agents' behaviour determining information–static data created by programmer and dynamic data collected by agent during its activity. Rules of conclusion transform accessible information using base of knowledge and makes possible adaptation process to environment. Teaching

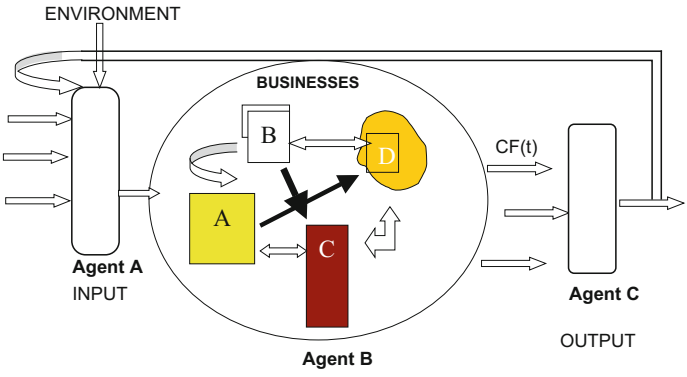

Fig. 8 Agent model of risk in company valuation

mechanism enables agent developing through knowledge, state of environment and effects of previous activity analysis. This mechanism modifies base of knowledge by adding knew notions, rules, data or by removing doubtful hypothesis.

4 Conclusion

Classical models use the random interpretation of the value factors and it takes into consideration the risk in valuation process. The value of the company calculated by DCF method is defined as a random variable. It will be possible to calculate the probability of getting the required value.

Discrete method of the company's risk valuation makes possible determining class of the company's risk and to add right cost of risk to discounted rate for example.

Dynamic environment changing and company internal factors changing influence company's value drivers and company's value. The classical methods are not good enough to describe the valuation process. Using IT technologies, agent technologies make possible dynamic valuation of the parameters.

Value based management requires specific tools that are able describe not only its variable parameters in static sense but its dynamic factors too. It makes possible interactive valuation. Using unconventional methods for modelling these specific and complicated process managers will be able creating, monitoring and controlling process of valuation. Dynamic development of computer sciences, hardware and software, is the way to look for resolving theoretical and practical managerial problems.

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Joint Treatment of Imprecision and Randomness in the Appraisal of the Effectiveness and Risk of Investment Projects

Bogdan Rębiasz, Bartłomiej Gaweł and Iwona Skalna

Abstract This paper proposes a new method for evaluating the effectiveness and risk of investment projects in the presence of both fuzzy and stochastic uncertainty. The main novelty of the proposed approach is the ability to take into account dependencies between uncertain model parameters. Thanks to this extra feature, the results are more accurate. The method combines non-linear programming with stochastic simulation, which are used to model dependencies between stochastic parameters, and interval regression, which is used to model dependencies between fuzzy parameters (possibility distributions). To illustrate the general idea and the effectiveness of the proposed method, an example from metallurgical industry is provided.

Keywords Risk of investment projects · Fuzzy random variable · Stochastic simulation · Interval regression

1 Introduction

It is well recognized that uncertainty is inevitable in economic evaluation models and consequently needs to be addressed appropriately in order that decision-makers have confidence in model's result. This would be possible only by using appropriate computational methods and tools for describing and processing uncertain data.

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For many years, probability theory was the only tool that allowed uncertainty to be expressed in mathematical language [5]. However, extensive research (see, e.g., [8, 9]) have shown that probabilistic approach faces several problems. For example, it is difficult to determine the probability distributions of economic parameters, when there is no sufficient data to perform statistical tests. Also, in many decision-making situations, the nature of uncertainty does not obey the assumptions of the probability theory. One can mention epistemic (reducible) uncertainty [14, 20], which stems from insufficient or imprecise information or the lack of knowledge or experts knowledge, which is usually expressed in linguistic terms. Therefore, alternative ways, such as fuzzy or intervals numbers, are increasingly often used to model uncertainty. The first works on using alternative ways to describe uncertain parameters in financial analyses have emerged in late '80s (see, e.g., [21]). Buckley [3] used fuzzy numbers to compute NPV of investment projects. Choobineh and Behrens [6] applied possibility distributions in economic analyses. Methods for computing effectiveness ratios of selected investment projects with fuzzy parameters were presented, e.g., in [7, 14, 13]. Kuchta [16] used fuzzy numbers in capital budgeting. Hui [11] discussed a capital budgeting problem in uncertain environment, where investment outlays and annual net cash flows of available projects are given subject to experts' estimations. The extend survey of using alternative methods of modelling uncertainty can also be found in [4].

Currently, probability theory and possibility theory are the most commonly used mathematical tools for describing uncertainty in effectiveness and risk appraisal problems. It is difficult to decide which approach is better [18], especially that the most common situation in practice is that some parameters are stochastic, whereas others are available in the form of imprecise knowledge, so that two types of uncertainty must be processed in a single framework. Most of the existing approaches handle this task by unifying different types of uncertainty [20], but this transformation is not one-to-one. The transition from possibility to probability introduces some (artificial) information, whereas in the opposite transition some information is lost [20], and thereby systematic errors are introduced in risk assessment. Therefore, it is better to process each type of uncertainty according to its nature.

In view of this, hybrid description of uncertainty, where some parameters are given by probability distributions, and others by possibility distributions was proposed, e.g., in [4, 6, 8, 9, 20]. A method for processing hybrid data, which combines stochastic simulation with fuzzy numbers was presented in [2, 10]. Hybrid approach was also successfully implemented in finance [13, 17], reliability theory [1] and LCA [19]. This direction of research becomes increasingly popular, but still has not been exhaustively investigated. One of the biggest deficiency of the existing methods for processing hybrid data, which limit their practical usage, is inability to take into account dependencies between hybrid parameters. In order to properly assess the risk, this problem must be solved. Baudrit et al. [2] have suggested how this problem can be tackled with rank correlations, copulas and some other techniques.

In this paper, a new method for processing hybrid data, which takes into account dependencies between uncertain parameters of the risk model is developed. The obtained results prove the truth of the following three hypotheses: (a) the use of both fuzzy numbers and probability distributions in assessment of the risk of investment projects provides a more adequate description of conditions under which decisions are made, (b) dependencies between hybrid data can be efficiently modeled by using correlation matrix and interval regression, (c) taking into account statistical dependence significantly improves the results, otherwise systematic errors in risk assessment may occur.

The rest of the paper is organized as follows. Section 2 describes a model for investment project risk appraisal. Section 3 presents an algorithm for processing hybrid data. Section 4 discusses a numerical example from the steel industry. The paper ends with concluding remarks.

2 Investment Project Risk Appraisal—Problem Statement

Effectiveness and risk of investment projects is estimated using a mathematical model, which consists of two groups of equations. The following notation is adopted:

$\boldsymbol{Pr}^{t}_{ij}$ - variable determining the quantity of the total output of product i in year t in department j,
$\boldsymbol{G}^{t}_{ia}$ - variable determining sales of the product i in year t in market a,
$\boldsymbol{ZO}^{t}$ - variable determining the operating profit in year t,
$\boldsymbol{NKO}^{t}$ - variable determining the change in working capital in year t,
IA - volume of investment outlays,
RV - the residual value of the project,
NPV - net present value
I, - index set of products
I_j - index set of products produced in department j,
J - index set of production departments,
A - index set of markets of the company,
B - index set of raw materials,
v^{t}_{j} - manufacturing capacity of department j in year t,
g^{t}_{ia} - forecasted sales for product i on market a in year t,
m^{t}_{ijz} - per unit consumption indicator of product i used for producing product z in department j in year t,
m^{t}_{bi} - per unit consumption indicator of raw material b used for producing product i in year t,

$\overset{\cdots}{t}$ - economic life of project of project,
c^t_{ia} - selling price of product i in year t on market a,
c^t_b - price of raw material b in year t,
kz^t_{ij} - variable processing cost for product i manufactured in production department j in year t,
rk^t - interest rate of short-term credit in year t,
rd^t - interest rate of long-term credit in year t,
r_{dys} - discount rate,
kf^t - company's fixed costs without amortization in year t,
χ^t - value of amortization in year t.

The first group of equations includes:

- manufacturing capacities balance for production departments

$$\sum_{i\in I_j} \boldsymbol{Pr}^t_{ij} \le v^t_j \text{ for } j \in J, t = 0,1,\cdots,\overset{\cdots}{t} \tag{1}$$

- material balance:

$$\sum_{j\in J} \boldsymbol{Pr}^t_{ij} - \sum_{j\in J}\sum_{z\in I_j} m^t_{ijz}\boldsymbol{Pr}^t_{iz} = \sum_{a\in A} \boldsymbol{G}^t_{ia}, \text{for } i \in I, \quad t = 0,1,\cdots,\overset{\cdots}{t}, \tag{2}$$

$$\boldsymbol{G}^t_{ia} \le g^t_{ia} \text{ for } i \in I, \text{a} \in A, t = 0,1,\cdots,\overset{\cdots}{t}, \tag{3}$$

The Eq. (1) determines the quantity and structure of the production of each department in consecutive years of a project lifecycle. The Eq. (2) determines the distribution of production of specific products for sales and for internal production usage. The Eq. (3) is the limitations for the amount of sale of production of specific products sold.

The second set of equations consists of financial equations. These linear equations determine specific items of a company's balance sheet, P&L account and cash flows (NCF), which are used to calculate NPV. For example, the equation for a company's operating profit has the following form:

$$\boldsymbol{ZO}^t = \sum_{i\in I}\sum_{a\in A} c^t_{ia}\boldsymbol{G}^t_{ia} - \sum_{j\in J}\sum_{i\in I_j} kz^t_{ij}\boldsymbol{Pr}^t_{ij} - \sum_{b\in B}\sum_{j\in J}\sum_{i\in I_j} c^t_b m^t_{bi}\boldsymbol{Pr}^t_{ij} - \chi^t - \boldsymbol{kf}^t \tag{4}$$

For $t = 1,\ldots,\overset{\cdots}{t}$.

$$NPV = \sum_{t=1}^{\dddot{t}} (ZO^t + \chi^t \pm ZKO^t) - IA - RV \tag{5}$$

In the Eq. (5), the variables ZO^t, χ^t, and ZKO^t are defined as increment in relation to the corresponding values without the investment project.

The remaining financial equations express commonly known dependencies. A detailed presentation of them would considerably increase the volume of the article, therefore, they are omitted.

In the proposed approach, it is assumed that some of the model parameters, $v_j^t, g_{ia}^t, m_{bi}^t, m_{ijz}^t, \dddot{t}, c_{ia}^t, c_{if}^t, c_b^t, kz_{ij}^t, \chi^t, kf^t$, can be described by probability distributions (stochastic parameters), and some others by possibility distributions (fuzzy parameters). Additionally, it is assumed that there are dependencies (correlation) between certain parameters.

3 Procedure of Determining *NPV* and Risk

The proposed procedure of determining the effectiveness and risk combines stochastic simulation with interval regression and non-linear programming. The computational procedure is as follows. The values of stochastic parameters are drawn taking into account dependencies represented by a correlation matrix [2]. Next, each fuzzy parameter is represented by a finite family of α-cuts, and then, for each α-level, dependencies between the α-cuts are determined by using interval regression [12]. Hence, fuzzy parameters are replaced with real variables x_i and the following additional constraints are imposed on the model defined in Sect. 2:

$$\inf(\tilde{\boldsymbol{X}}_i)_\alpha \le x_i \le \sup(\tilde{\boldsymbol{X}}_i)_\alpha \tag{6}$$

$$\boldsymbol{x}_i \ge \inf(a_1^{iz}) \cdot \boldsymbol{x}_z + \inf(a_2^{iz}) \tag{7}$$

$$\boldsymbol{x}_i \le \sup(a_1^{iz}) \cdot \boldsymbol{x}_z + \sup(a_2^{iz}) \tag{8}$$

where:

$\inf(\tilde{\boldsymbol{X}}_i)_\alpha, \sup(\tilde{\boldsymbol{X}}_i)_\alpha$ - lower and upper bound of an α-cut of the fuzzy parameter $\tilde{\boldsymbol{X}}_i$,

$\sup(a_1^{iz}), \inf(a_1^{iz}), \sup(a_2^{iz}), \inf(a_2^{iz})$ - lower and upper bounds of interval regression coefficients describing the dependency between the fuzzy parameters $\tilde{\boldsymbol{X}}_z$ and $\tilde{\boldsymbol{X}}_i$

Algorithm 1. Method for evaluating the effectiveness and risk of investment projects

START

Step 1. $n = 1$ // set the number of the current iteration to 1

Step 2. Randomly generate a vector of probabilistic variables taking into account the dependencies given in the form of the correlation matrix

Step 3. $\alpha = 0$ // set the starting α-level

Step 4. Calculate α-cuts of the fuzzy parameters

Step 5. Calculate constraints (6)-(8) by using interval regression

Step 6. Solve the nonlinear programming problems (9), (10), s.t. constraints (1)-(8)

Step 7. $\alpha = \alpha + \wp$ // take next α-level

Step 8. If $\alpha \leq 1$ goto Step 4 else $n = n + 1$

Step 9. If $n \leq \ddot{n}$ goto Step 2 // $\ddot{n}$ - number of iterations

Step 10. Define the set possibility distributions ($\mu_1^{NPV}, \cdots, \mu_{\ddot{n}}^{NPV}$)

Step 11. Calculate a p-box for the random fuzzy number ($\mu_1^{NPV}, \cdots, \mu_{\ddot{n}}^{NPV}$)

STOP

Next, for each α-level the two following nonlinear programming problems are solved:

$$NPV_\alpha \rightarrow \min, \text{s.t.}(1)-(8), \tag{9}$$

$$NPV_\alpha \rightarrow \max, \text{s.t.}(1)-(8). \tag{10}$$

As a result a family of α-cuts $NPV_\alpha = [NPV_\alpha^{\min}, NPV_\alpha^{\max}]$ is obtained, which can be considered as a possibility distribution μ^{NPV}. The overall procedure is repeated $\dddot{n}$ times, and the set of possibility distributions $\left(\mu_1^{NPV}, \ldots, \mu_{\dddot{n}}^{NPV}\right)$, which can be considered as a random fuzzy set [15], is obtained. Based on this set, a p-box (probability box) is determined. It can be used to characterize uncertainty having both aleatory and epistemic nature. The details on computing a p-box can be found, e.g., in [2].

The hybrid procedure which implements the described approach is presented in Algorithm 1.

4 Numerical Example

The performance of the proposed method is verified on the example of a project of construction of sheet organic coating plant for metallurgical industry enterprise. The assessment of the effectiveness and the risk is performed for the production setup, which is presented in Fig. 1. This setup includes the four production departments (J) which need one raw material—continuous casting stand and produces four outputs. The value of v_j^t, which is put in Fig. 1 next to the department's name, is constant for each department.

In such investment projects, demand, sales prices, costs of materials and a value of investment outlays are potential sources of uncertainty. Table 1 shows fuzzy input parameters as trapezoidal possibility distributions and stochastic parameters as normal probability density functions specifying forecast of parameters for the year t = 0 of economic life of an investment project.

In order to simplify the computations, it is assumed that the apparent consumption of metallurgical products will increase by 1.5 % per year. Whereas, prices of products and material consumption indicator will be constant. It also assumed that production setup sells products on only one market (a = 1). The volume of investment outlays is assumed to be a triangular fuzzy number (42,000, 46,000, 50,000) given in thousands USD.

The value of the fixed cost kf^t is determined at the level of USD 315 090 thousand per year. The adjusted unit processing cost kz_{ij}^t for particular product

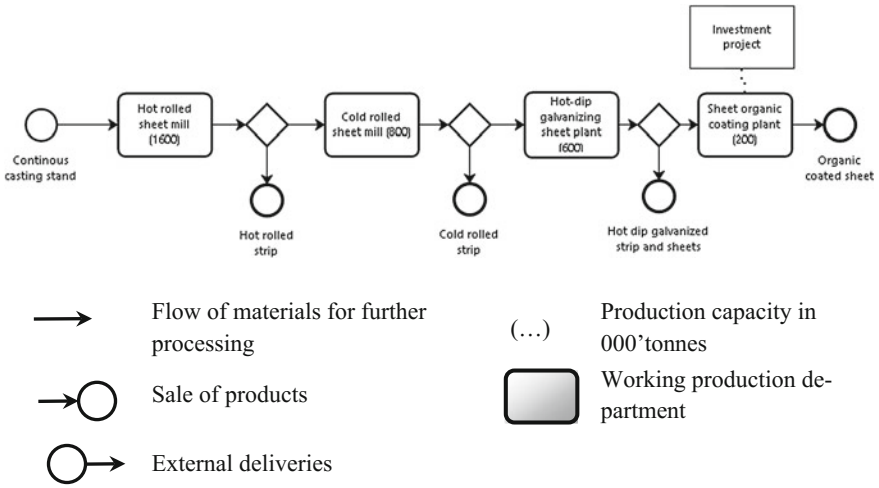

Fig. 1 Diagram of the analyzed production setup

Table 1 Trapezoidal fuzzy numbers representing forecasts of products and raw material prices, material consumption indicators and parameters of normal probability density function characterizing apparent consumption of metallurgical products

Purchasing c_i^t and selling prices c_i^t	Trapezoidal fuzzy numbers, USD/t
Continuous casting stands (purchase)	(440.3, 445.0, 450.7, 460.3)
Hot rolled strip (sell)	(666.7, 680.0, 711.7, 728.3)
Cold rolled sheets (sell)	(715.0, 730.0, 763.3, 781.7)
Hot dip galvanized strip and sheets (sell)	(805.0, 821.7, 860.0, 880.0)
Organic coated sheets (sell)	(1,080.0, 1,101.7, 1,153.3, 1,175.0)
Material consumption indicator m_{ijz}^t	Trapezoidal fuzzy numbers, tons/t
Continuous casting stands—hot rolled strip	(1,058, 1,064; 1,075, 1,078)
Hot rolled strip—cold rolled sheets	(1,105, 1,111, 1,124, 1,130)
Cold rolled sheets—hot dip galvanized strip and sheets	(1,010, 1,020, 1,026, 1,031)
Hot dip galvanized strip and sheets—organic coated sheets	(0,998, 0,999, 1.000, 1.001)
Apparent consumption g_i^t	(Average [thousand. tons]; standard deviation [thousand. tons])
Hot rolled strip	(2,704.0, 117.5)
Cold rolled sheets	(1,162.3, 51.4)
Hot dip galvanized strip and sheets	(1,147.9, 52.4)
Organic coated sheets	(708.4, 30.8)

Table 2 Unit processing cost for particular product ranges

Product	Hot rolled strip	Cold rolled sheets	Hot dip galvanized strip and sheets	Organic coated sheets
Adjusted unit variable processing cost, USD/tone	28.4	28.0	116.7	175.3

ranges is presented in Table 2. As soon as one department produces each product, unit processing cost may be simplified to four variables.

Table 3 presents coefficients of the interval regression equation characterizing relations between prices of product manufactured by analyzed producer and prices of continuous casting stands. Table 4 presents matrix of correlation of apparent consumption of particular product ranges manufactured by the producer.

Table 3 Interval regression equations coefficients depicting interrelations between prices of particular product ranges produced by the manufacturer in question prices of raw materials

		Dependent variable				
		Continuous casting strand v_1	Hot rolled strip v_2	Cold rolled sheets v_3	Hot dip galvanized strip and sheets v_4	Organic coated sheets v_5
v_1	a_1		[0.70, 0.88]	[0.39, 0.56]	[0.35, 0.45]	[0.31, 0.42]
	a_2		[3.66, 4.59]	[101.81,143.90]	[101.80,131.01]	[49.311, 66.675]
v_2	a_1	[1.05, 1.33]		[0.59, 0.79]	[0.48, 0.66]	[0.39, 0.66]
	a_2	[22.01,28.01]		[112.16,148.39]	[112.60,155.43]	[31.68, 53.31]
v_3	a_1	[0.49, 0.69]	[0.86, 1.40]		[0.753, 0.917]	[0.570, 0.955]
	a_2	[128.78,180.53]	[−10.59, −17.12]		[−2.17, −2.65]	[−95.30, −159.72]
v_4	a_1	[0.44, 0.56]	[0.96, 1.50]	[0.98, 1.22]		[0.59, 1.06]
	a_2	[127.51,162.70]	[45.66, 71.29]	[57.87, 72.08]		[−48.89, −87.59]
v_5	a_1	[0.34, 0.53]	[0.35, 0.86]	[0.80, 1.31]	[0.63, 1.12]	
	a_2	[69.20, 107.60]	[385.56, 941.97]	[248.17, 403.48]	[236.97, 420.88]	

Table 4 Correlation between the apparent consumption of metallurgical products manufactured by analyzed company

	Hot rolled strip	Cold rolled sheets	Hot dip galvanized strip and sheets	Organic coated sheets
Hot rolled strip	1.000	0.878	0.911	0.863
Cold rolled sheets	0.878	1.000	0.915	0.888
Hot dip galvanized strip and sheets	0.911	0.915	1.000	0.966
Organic coated sheets	0.863	0.888	0.966	1.000

Figure 2 compares lower and upper cumulative distribution functions for NPV_1 and NPV_2. (NPV_1 was calculated taking into account the correlation of the price and apparent consumption, and NPV_2 without taking this correlation into account).

The results indicate that the dependencies between the model parameters have a considerable impact on the *NPV* of a project.

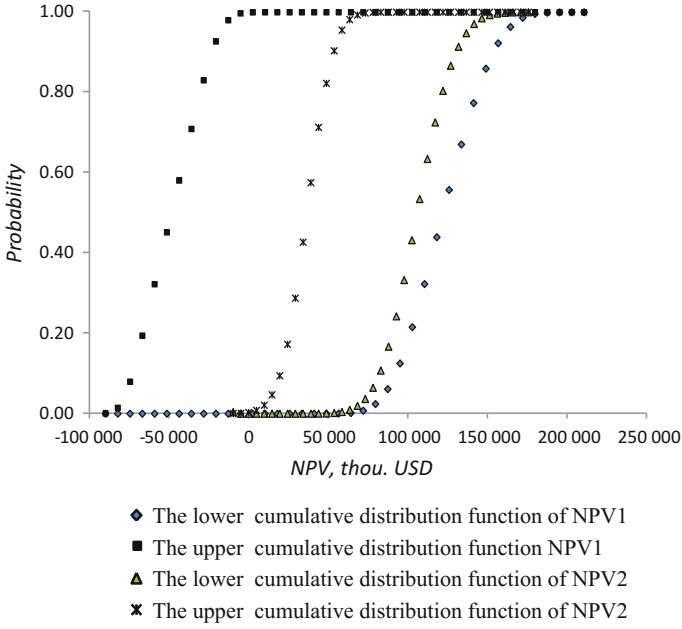

Fig. 2 Upper and lower cumulative distribution functions depicting *NPV1 and NPV2*

5 Conclusions

The new method for processing hybrid data is developed in this work. The proposed method equips decision-makers with a formal language for defining dependencies between uncertain parameters in decision making models. The method improves previous works concerning the processing of hybrid data. First of all this method allows to take into account dependencies between the fuzzy parameters. Moreover, it can be used in the case of arbitrary possibility distributions, since the calculations are performed on α-cuts. The method is flexible, since with minor changes it can be used to solve many other problems.

The obtained results indicate that the dependencies between the decision model parameters has a considerable impact on the estimated value of NPV. Omitting this dependencies can cause a considerable systematic error.

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Analysis of the Insurance Portfolio with an Embedded Catastrophe Bond in a Case of Uncertain Parameter of the Insurer's Share

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Abstract In this paper, a behavior of an insurer's portfolio, which consists of two layers: a classical risk process and a special financial instrument, which is known as a catastrophe bond, is analyzed. Especially, a probability of a ruin for such a portfolio is estimated using the Monte Carlo simulations. A special attention is given to a problem of an insurer's share in a whole insurance market, which associates values of the catastrophic losses with values of the claims for the considered insurer. It is also an important source of a systematic risk. Because such a share is often an uncertain parameter, then a fuzzy number is used to model its value. This approach incorporates the experts' knowledge. Based on the simulations, observed differences between a crisp and a fuzzy case are described in a more detailed way.

Keywords Risk process · Insurance portfolio · Catastrophe bond · Monte carlo simulations · Fuzzy numbers

1 Introduction

One of the main problems in an insurance industry is to evaluate a probability of an insurer's ruin. If, apart from a classical risk process, other kinds of financial and insurance instruments are taken into account, then this problem is an even more complex one and it requires a solution based on simulations. A catastrophe bond (abbreviated as a cat bond) is an example of such a special, financial instrument used by the insurers nowadays. A catastrophe bond (see, e.g., [5, 8–10]) is a part of a process, which is known as a securitization of losses, i.e. it is used to "package" the catastrophic losses (i.e., losses with extreme high values, but rather infrequent, comparing to the "standard" losses, usually considered by the insurers) into tradable

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financial assets, in the form of so-called catastrophe derivatives. A payoff received by a cat bond holder depends on an additional random variable, i.e. a triggering point. The triggering point is usually related to a cumulated value of the catastrophic losses (caused by hurricanes, tsunamis, floods etc.). If the losses, defined in a description of the cat bond, surpasses some given limit, then the payoff from this instrument is lowered, comparing to a contrary case. Then these additional funds are transferred to the insurer, which issued this cat bond.

In this paper, using the Monte Carlo simulations, we analyze a behavior of an insurer's portfolio, which consists of a classical risk process and an additional catastrophe bond, issued by the insurer. A probability of the ruin for such a portfolio and some other statistical measures are estimated. This analysis may be seen as an improvement and a reformulation of the problem stated in [10]. But in this paper, instead of a completely crisp approach, a parameter, which describes a share of the insurer in a whole insurance market, is given as a fuzzy number. It allows us to incorporate the experts' knowledge and to analyze possible differences in estimated probabilities of a ruin, if the mentioned parameter is, in some way, uncertain. This new approach requires also a completely different way of applying the Monte Carlo simulations.

This paper is organized as follows. In Sect. 2, models of processes of the aggregated losses and of an interest rate are introduced. Section 3 is devoted to a description of the insurer's portfolio, which consists of two layers: the classical risk process and the catastrophe bond. Simulated outputs for such a portfolio are numerically analyzed in Sect. 4 for two cases: if a share parameter is given as a crisp and as a fuzzy number. Then some significant differences in the obtained results, especially the probabilities of the ruin and some other statistical measures, are discussed.

2 Applied Models

Traditionally, in the insurance industry, a process N_t^* of the aggregated losses caused by the natural catastrophes is given by

$$N_t^* = \sum_{i=1}^{N_t} U_i, \tag{1}$$

where number of losses $N_t \geq 0$ is modeled by some stochastic process (e.g., a homogeneous Poisson process—HPP, or a non-homogeneous Poisson process—NHPP) and values of single claims are given by an iid random sequence $U_1, U_2, \ldots$ In our setting, we assume that N_t is given by the NHPP with a cyclic intensity function

$$\lambda_{NHPP}(t) = a + b2\pi \sin(2\pi(t - c)), \tag{2}$$

where $a = 30.875, b = 1.684, c = 0.3396$. These parameters are estimated in [3] using the data from the United States, provided by the Property Claim Services (PCS) of the ISO (Insurance Service Office Inc.). Based on the same source, the value of the single loss U_i can be modeled by the lognormal distribution with the parameters $\mu_{LN} = 17.357, \sigma_{LN} = 1.7643$.

We are interested in a present or a future value of the considered cash flow (see also [10] for a more detailed discussion), so a relevant interest rate model should be also introduced. This model reflects the value of money in time. In this paper, we apply the one-factor Vasicek model, given by

$$dr_t = \kappa(\theta - r_t)dt + \sigma dW_t, \tag{3}$$

where the parameters $\kappa = 0.1179, \theta = 0.086565, \sigma^2 = 0.0004$ are fitted in [2] for the U.S. Treasury bill yield data.

As for a payment function $f\left(N_T^*\right)$ for a holder of the considered cat bond, a piecewise linear function is applied. This form of the payment function is introduced and discussed in details in [5, 8–10]. Then, we have

$$f\left(N_T^*\right) = Fv\left(1 - \sum_{i=1}^{n} \frac{\min\left(N_T^*, K_i\right) - \min\left(N_T^*, K_{i-1}\right)}{K_i - K_{i-1}} w_i\right), \tag{4}$$

where Fv is a face value of the cat bond, $w_1, \ldots, w_n > 0$ are payoff decreases (satisfying the requirement $\sum_{i=1}^{n} w_i \leq 1$), and $0 \leq K_0 \leq K_1 \leq \ldots \leq K_n$ are the triggering points. In the considered setting, we set $Fv = 1$ (one monetary unit assumption), and

$$K_0 = Q_{NHPP-LN}^{loss}(0.75), K_1 = Q_{NHPP-LN}^{loss}(0.9), \tag{5}$$

where $Q_{NHPP-LN}^{loss}(x)$ is xth quantile of a cumulated value of losses, if the number of losses is given by the NHPP and the value of the single loss is modeled by the lognormal distribution (see also [5, 9, 10] for additional details). The payoff decrease is given by $w_1 = 1$ and we apply one year time horizon, so $T = 1$. It means that, if after one year, the cumulated value of losses surpasses K_1, the bond holder receives nothing.

In order to evaluate the price of the cat bond determined by the previously mentioned parameters, the approach, considered in a more detailed way in [5, 8–10], is then applied. The cat bond pricing problem is a complex one, and requires analytical formulas, introduced in [5, 8–10], and the additional Monte Carlo simulations. Then, the price of the cat bond, which is considered here, is estimated as $I_{cb} = 0.809896$. This value will be used further on during an analysis of the insurer's portfolio.

3 Model of the Insurer's Portfolio

In this section the model of the insurer's portfolio, which consists of a few layers (i.e. an additional financial instrument) is discussed in a more detailed way.

3.1 Risk Reserve Process

Usually, in insurance mathematics, a risk reserve process R_t is defined as a model of evolution of the financial reserves of an insurer depending on time t, and is given by

$$R_t = u + pt - C_t^*, \tag{6}$$

where u is an initial reserve of the insurer, p is a rate of premiums paid by the insureds per unit time and C_t^* is a claim process, which is equal to $C_t^* = \sum_{i=1}^{N_t} C_i$, so that $C_1, C_2 \ldots$ are iid random values of the claims.

In the considered setting, the process of the number of claims (the same as the number of losses) is modeled by the NHPP with the intensity function (2). Therefore, similarly to the classical approach, the premium is also a constant function but directly related to $\lambda_{NHPP}(t)$, so that for the fixed moment T we have

$$p(T) = \big(1 + v_p\big) EC_i \int_0^T \lambda_{NHPP}(s) ds, \tag{7}$$

where v_p is a safety loading (a security loading) of the insurer. Usually, this loading is about 10–20 %.

In insurance mathematics, we are interested in an evaluation of a probability of an ultimate ruin (i.e. a ruin with an infinite time horizon)

$$\psi(u) = Pr(inf_{t \geq 0} R_t < 0) \tag{8}$$

or a probability of a ruin before time T (i.e. a ruin with a finite time horizon)

$$\psi(u, T) = Pr\big(inf_{t \in [0,T]} R_t < 0\big). \tag{9}$$

Similar probabilities are estimated further on, using the Monte Carlo approach (see also [10] for additional details).

3.2 Additional Layer—Catastrophe Bond

We assume, that the insurer also issues a catastrophe bond, which forms an additional layer in his portfolio. Then, apart from the risk process (6), the cash flows related to this cat bond should be taken into account. The hedger (e.g. the insurer) pays an insurance premium p_{cb} in exchange for a coverage, when the triggering point (i.e. some catastrophic event) occurs. The investors purchase an insurance-linked security for cash. The above mentioned premium and cash flows are usually directed to a SPV (Special Purpose Vehicle), which issues the catastrophe bonds. The investors hold the issued assets whose coupons and/or a principal depend on the occurrence of the triggering point. If such a catastrophic event occurs during the specified period, the SPV compensates the insurer and the cash flows for the investors are changed. Usually, these flows are lowered, i.e. there is full or partial forgiveness of the repayment of principal and/or interest. However, if the triggering point does not occur, the investors usually receive a full payment.

Let us assume, that the mentioned insurance premium p_{cb} is proportional to both a part α_{cb} of the whole price of the single catastrophic bond I_{cb}, and to a number of the issued bonds n_{cb}, so that $p_{cb} = \alpha_{cb} n_{cb} I_{cb}$.

Taking into account the previously mentioned value of money in time, the future value of the cash flows for the insurer's portfolio, if the catastrophe bond was issued, is given by

$$R_T = FV_T(u - p_{cb}) + FV_T(p(T)) - FV_T\left(C_T^*\right) + n_{cb} f_{cb}^i\left(N_T^*\right), \tag{10}$$

where $FV_T(.)$ denotes a future value of the cash flow, and $f_{cb}^i\left(N_T^*\right)$ is a payment function of the single cat bond for the insurer. Such a function is, in some way, "opposite" to the payment function $f\left(N_T^*\right)$ for the policy holder (given by (4) in our case).

3.3 Claims Versus Losses

As presented in Sects. 2 and 3.1, the process of the aggregated losses N_t^* and the process of the cumulated claims C_t^* are driven by the same process of the number of the catastrophic events N_t in our setting. However, further on, we assume that the value of the single claim C_i is only some deterministic part of the related loss U_i, i.e. $C_i = \alpha_{claim} U_i$. Such an approach models the situation, when there is no monopoly on the market, so the considered insurer has only some share of a whole insurance market. It also leads to a systematic risk, because a hedging instrument (i.e., the catastrophe bond) is issued for a process (in this case—the process of the aggregated losses) which is not exactly the same as a process which should be hedged (i.e. the process of aggregated claims).

In the following, we assume, that an exact value of the share parameter α_{claim} is unknown. Such an assumption reflects the situation, when, e.g. the level of the share of the insurer in the whole market is not exactly stated, this level varies depending on a region of a possible natural catastrophe or its source (e.g. earthquake or tsunami) etc. Therefore, the parameter α_{claim} will be given as a fuzzy number. It means, that this uncertain value is related to the experts' knowledge.

4 Simulations

Now we turn to analysis of the insurer's portfolio, which consists of the "classical" risk process with addition of the issued catastrophe bond. Based on the Monte Carlo simulations, an analysis of behavior of the process (10) will be conducted in two main cases: if the share parameter α_{claim} is given as a crisp, real value and if such a parameter is modeled by a triangular fuzzy number.

4.1 Analysis of the Crisp Case

Let us assume, that for the first layer (the risk process), we have $u = Q^{claim}_{NHPP-LN}(0.25)$, i.e. the initial reserve of the insurer is equal to 0.2 quantile of the cumulated value of the claims driven by the process C^*_t, and $\alpha_{claim} = 0.5$. Then, the share of such an insurer in the whole insurance market is equal to 50 %, so the half of the value of each catastrophic loss is turned into the claim for this insurer. We also set $v_p = 0.1$, and the process of the losses and the Vasicek interest rate model are described by the parameters introduced in Sect. 2.

The second layer consists of the catastrophe bond, which is discussed in Sects. 2 and 3.2. We assume that the number of the issued cat bonds is related to a difference between quantiles of the cumulated value of the claims, namely it is equal to $Q^{claim}_{NHPP-LN}(0.9) - Q^{claim}_{NHPP-LN}(0.75)$. It reflects the situation, when the cat bond is used as an additional source of "possible" funds, if the value of the claims is too high and there is a high probability of the insurer's ruin. Therefore, the cat bond may be seen as an alternative instrument to a reinsurance contract, which is not, in many cases, an adequate source of funds for the insurer (see also [10]). Then, if $N^*_T > K_1$ (i.e. the cumulated value of the losses surpasses the highest triggering point), the income for the insurer from the issued n_{cb} cat bonds is equal to the previously mentioned difference of the quantiles. We assume that $\alpha_{cb} = 0.1$, so this value is similar to v_p. Then we get $n_{cb} = 1481$.

Using the Monte Carlo simulations, a probability of a final ruin (i.e. $\mathrm{P}(R_T < 0)$ for $T = 1$) is estimated as 5.3677 %, and a probability of an earlier ruin (i.e. $\mathrm{P}(R_t < 0)$ for some $t \in (0, t]$) is equal to 18.4852 %. It means that a probability of a ruin which does not lead to the final ruin is estimated as 13.1175 %. This rather

Table 1 Statistical measures of the final value of the insurer's portfolio and the payments for the insurer in the crisp case

	Final value of the portfolio	Payments for the insurer
Minimum	–262500	0.00297548
Median	1987.47	1095.07
Mean	1739.47	957.306
Maximum	5007.92	1481
Stand. deviation	1868.66	535.415

high value is related to a necessity of an early payment for the issued bonds, even if these instruments are not used afterwards. A probability that the catastrophe bond is used (i.e. at least one triggering point is achieved) is equal to 24.8908 %. Also other statistical measures of the final value of the insurer's portfolio R_T, which are important for the practitioners, can be directly found using simulations (see Table 1 for some examples). Similar characteristics can be obtained also for non-zero values of f_{cb}^i, i.e. the non-zero payments from the catastrophe bond directed to the insurer (see Table 1).

4.2 Analysis of the Fuzzy Case

As it was previously mentioned, the share parameter α_{claim} is now given in a fuzzy form, as a fuzzy triangular number. A triangular fuzzy number $\tilde{a}$ (see, e.g., [1, 8, 9, 11] for necessary details and definitions of fuzzy sets and fuzzy numbers) is a fuzzy number with a piecewise linear membership function of the form

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{x-a}{b-a}, \textit{if } x \in [a,b] \\ \frac{x-c}{b-a}, \textit{if } x \in [b,c] \\ 0, \textit{otherwise} \end{cases}, \tag{11}$$

so such a number can be denoted further on as $[a, b, c]$, where a support of this number is given by the interval $[a, b]$. Using a fuzzy number, the experts' knowledge can be easily incorporated into the considered problem. Then, instead of a precise statement "the share of the insurer in the whole market is equal to 50 %" as in the previous, crisp case considered in Sect. 4.1, the experts can say "the share is about 50 %". This second statement models imprecise information, which is based on other sources than a statistical inference. Such an approach is also useful for the practitioners, if necessary information is sparse or even unavailable (see, e.g., [4] for fuzzy applications in statistics). Therefore, during our analysis we assume that $\tilde{\alpha}_{claim} = [0.4, 0.5, 0.6]$, so the support of this fuzzy number is from 40 % up to 60 % percent of the share of the whole insurance market, and for $\alpha = 1$ we have the same

value, as in the case considered in Sect. 4.1. Then, for this example the expert can say "the share of the insurer is about 50 % plus/minus 10 %".

In order to estimate the probabilities and the statistical measures similar to the previous, crisp case, the Monte Carlo simulations are also performed. Because now the evaluated output is a fuzzy number $\tilde{a}$, then it is approximated by α-level sets $\tilde{a}[\alpha]$ for a whole range of possible values of α. For the given α, if $f(x)$ is an increasing function of x, then a left end point of the considered output $\tilde{f}_L[\alpha]$ is approximated using a left end point of an α-level set of the fuzzy value $\tilde{x}$, i.e. $\widetilde{x_L}[\alpha]$. In the same way, $\widetilde{x_R}[\alpha]$ (a right end point of $\tilde{x}$) is used to find $\tilde{f}_R[\alpha]$ (a right end point of the output). This idea is related to the Zadeh's extension principle (see, e.g., [11]) and it is also used in other areas of financial mathematics (see, e.g., [6–9] for applications in derivatives pricing and decision making problems).

During the Monte Carlo simulations, the parameter α is changed from some starting value $\alpha_0 > 0$ up to an upper bound $\alpha_1 \in (\alpha_0, 1]$ with an increment $\Delta\alpha > 0$. After the evaluation of the left and right end points of the different α-level sets of the considered function of the output, i.e. $\left[\tilde{f}_L[\alpha], \tilde{f}_R[\alpha]\right]$, the obtained intervals are put on one another, so they form an approximation of a final fuzzy outcome $\tilde{f}$.

In this way, we get fuzzy approximations of the probabilities of the final ruin (Fig. 1, left hand side) and the earlier ruin (Fig. 1, right hand side). They form L-R numbers with rather wide supports. For example, for $\alpha = 0$ and the probability of the final ruin, we get the interval $[3.8526, 6.7769]$. Then, relative differences (if we are comparing to the probability for $\alpha = 1$) are equal to –28.2236 % (the left end point of the mentioned interval) and 26.258 % (the right end point). It means that the probabilities of the ruin significantly varies, if the share of the insurer in the whole market is not given in a completely exact way (i.e. it is not stated as a crisp, real number). Then, a wrong assumption about the share can be dangerous for an estimation of the probability of the insurer's ruin and it can lead to serious error of the whole procedure.

In the same manner, based on the output from the Monte Carlo simulations, fuzzy approximations of the statistical measures of the final value of the insurer's

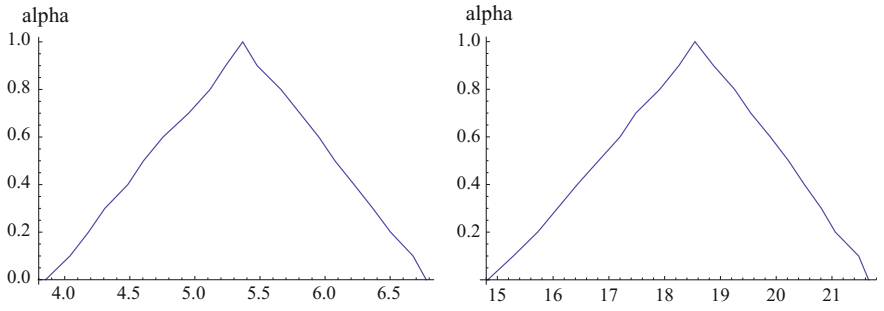

Fig. 1 Fuzzy approximations of the probability of the final probability ruin (*left*) and the earlier ruin (*right*)

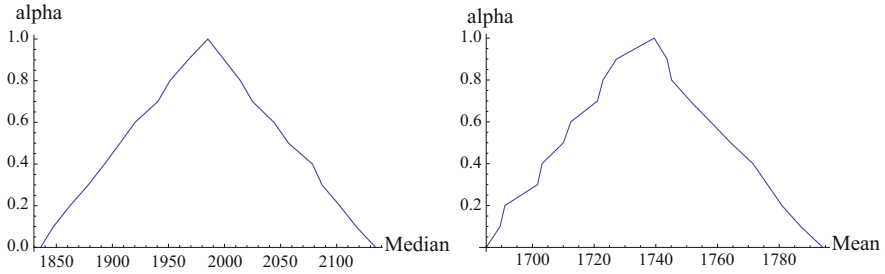

Fig. 2 Fuzzy approximations of the measures of the insurer's portfolio: median (*left*) and mean (*right*)

portfolio can be found. As relevant examples, a median and a mean are plotted in Fig. 2 (graphs on the left and right hand side, respectively). Once again, they form L-R numbers. It seems, that median is a better idea in measuring the value of the portfolio, because the obtained fuzzy approximation is much smoother. The median is also more resistant to outliers, which are very common in the generated data. This reasoning can be supported by a quantiles plot for the final value of the insurer's portfolio. An example of such a graph for $\alpha_{claim} = 0.4$ can be found in Fig. 3. As it is easily seen, the quantiles of lower ranks (especially, the quantiles of ranks <0.1) have extremely low values, which indicates a problem with the outliers. A very similar situation exists for other values of the parameter α_{claim}. Moreover, the relative differences for median (if the relevant values of the median for $\alpha = 0$ and $\alpha = 1$ are, as previously, compared) are equal to –7.51487 % (for the left end point of the support) and 7.54409 % (for the right end point). These differences are significant, but a possible error is less dangerous than during the estimation of the probabilities.

Apart from the final ruin, the moments of the earlier ruin can be also analyzed using the output generated during the simulations. For example, the times of such events can be compared for $\alpha_{claim} = 0.4$ (which corresponds to the left end point of the α-level set for $\alpha = 0$, see Fig. 4, squares) and $\alpha_{claim} = 0.6$ (which corresponds to the right end point of the α-level set for $\alpha = 0$, see Fig. 4, circles). It is easily

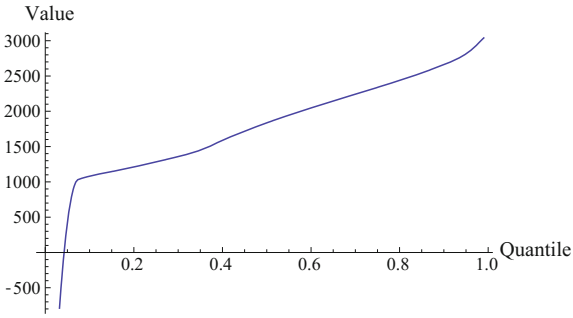

Fig. 3 Graph of the quantiles of the final value of the insurer's portfolio for $\alpha_{claim} = 0.4$

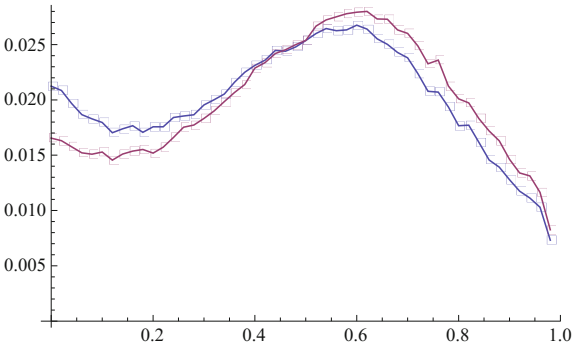

Fig. 4 Comparison of envelopes of histograms for the moments of the earlier ruin for $\alpha_{claim} = 0.4$ (squares) and $\alpha_{claim} = 0.6$ (circles)

seen, that the envelopes of the histograms of these times have similar shapes. However, up to about $t = 0.55$, a relevant frequency of the earlier ruins is higher for $\alpha_{claim} = 0.6$, afterwards the situation is quite opposite. Of course, as it was previously mentioned, the probability of the earlier ruin itself is higher for the higher value of α_{claim}.

5 Conclusions

In this paper, the behavior of the insurer's portfolio is analyzed. Such a portfolio consists of the two layers: the classical risk process and the special financial derivative, known as the catastrophe bond. A special interest is paid to the future value of this portfolio, i.e. its value for some final moment T. Therefore, the model of the interest rate, known as the one factor Vasicek model, is applied. Then, based on the Monte Carlo simulations, various probabilities and statistical measures for the portfolio are estimated. For both the model of the cumulated value of the catastrophic losses, and the interest rate model, the parameters from the real life data are applied. During the simulations, the influence of the share of the insurer in the whole insurance market on the characteristics of the portfolio is analyzed. Two main cases are considered: if the share parameters is given as a crisp value and if it is given as a fuzzy, triangular number. For these two cases, the examples of simulated output are provided and discussed in a more detailed way. The fuzzification of the share parameter introduced in this paper allows us to overcome the problem of uncertainty of data.

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How Can the Fractal Geometry Help with Analyze of the Stock Exchange Market?

Anna Czarnecka and Arkadiusz Górski

Abstract Currently, more and more scientists seek interdisciplinary solutions which will allow to have more detailed studies on the phenomena occurring in capital markets. That's why, the main goal of this paper is to shows the capabilities which fractal methods give when used for capital market analysis. The practical part of the paper focuses on the Warsaw Stock Exchange (WIG) index analysis with the use of the Detrending Fluctuation Analysis (DMA) method.

Keywords Fractal · Hurst exponent · Stock exchange · DMA

1 Introduction

A breakthrough in the process of a risk analysis on the financial markets was made by the French mathematician—B. B. Mandelbrot. Most of his work was dedicated to the objects, which can be characterized as being irregularly shaped, self-similar and for which one cannot determine their Euclidean dimension [4]. Those objects are nowadays called fractals (fractal geometry). The emergence of the new geometry form shows that Euclidean geometry, which studies the regular, full shapes (e.g. straight line—one dimension, triangle—two dimensions, tetrahedron—three dimensions, etc.) is insufficient as a tool to conduct research on the objects, which are more complex than simple Euclidean geometry. The basic feature characterizing fractals, self-similarity, can be simply defined as the feature that the exact same shapes/formations are visible in every scale that observe the object [13]. At the beginning, fractal studies have been devoted only to deterministic fractals like the Sierpinski triangle (Fig. 1) or the Koch snowflake (Fig. 1), which are geometric examples that do not appear in any kind of analyzed data. After some

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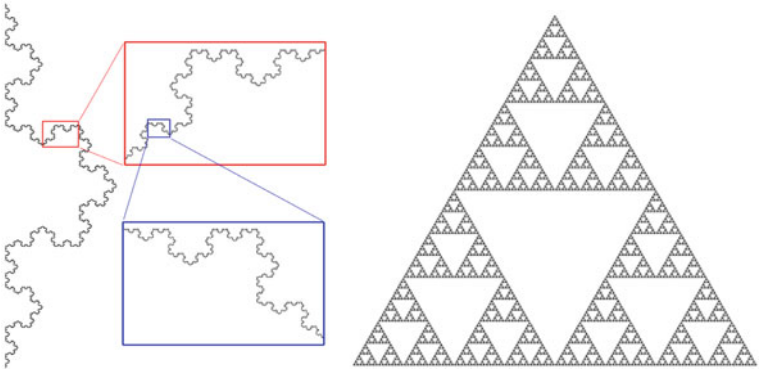

Fig. 1 Plot of Koch snowflake (*left*) [16] and Sierpinski triangle (*right*) [20]

time, a fractal structure was recognized in natural environment. That kind of self-similarity was often imperfect or not entirely deterministic and therefore such objects were called random fractals. That group of fractals is used in a variety of areas, for example: the coastline of Britain [12], avalanches [9], DNA analysis [19], heart rate analysis [2] or stock exchange changes [3, 5, 17].

Fractals, as well as Euclidean objects, are often categorized by their dimension. Unfortunately, fractal dimension still isn't clearly defined, that's why there are many ways to determining it. This doesn't change the fact that fractals have fractional dimensions, which is the result of the irregular and infinitely self-similar shape of the analyzed object. It indicates the degree of filling the space in which it's located. For a fractal, which is characterized by a high self-similarly (deterministic fractal), the degree of filling the space is usually estimated by a parameter, which is called the dimension of self-similarity. Calculation of the fractal dimension ($\boldsymbol{D_s}$) by using self-similarity dimension. It's based on the ratio between a function of the number of details/elements visible in a given scale and the reduction factor (**s**) which describes the scale:

$$D_s = \frac{log(N)}{log\left(\frac{1}{s}\right)} \tag{1}$$

Usually, this method (Eq. 1) is used to calculate the fractal dimension for artificial fractals (deterministic), for which the reduction factor, known also as scale factor, is easy to determine. For example, when considering the Sierpinski triangle (Fig. 1), in which one change of scale (which can be viewed as increasing the resolution) consists of recreating each triangle with is an exact copy of the original full "triple" triangle. In this case, the first step gives three new objects (3^n, where n is the number of steps taken), which are created by dividing the side of triangle in half ($s = \frac{1}{2}$). Substituting this data into the Eq. (1), the fractal dimension for the Sierpinski triangle is equal to:

$$D_s = \frac{\log(3)}{\log(2)} = 1.585 \tag{2}$$

The problem with using this methods, becomes apparent when one tries to analyze random fractal. For them, the reduction factor is difficult, and sometimes even impossible to determine. Because of this, a new method of determining fractal dimension has been developed [8]. This method was created by H. E. Hurst in the process analyzing water levels in a river in the form of a data series. Thanks to this, it can be used for all data that can be transformed into some data/time series. This method is based on the Hurst exponent (**H**) which depends it is related to the fractal dimension:

$$D_s = 2 - H \tag{3}$$

From the Eq. (3) one can see, that the Hurst exponent can be defined as the degree of roughness of the analyzed object. The range of this parameter is (0; 1) and this range can be divided into three groups based on their properties. The first range is for the Hurst exponent between $<0; 0.5)$, for which the data series is characterized by large number of fluctuation (i.e. frequent change of direction) and is called antipersistence (Fig. 2 bottom plot). The opposite of this state is data persistence (Fig. 2 top plot) and it can be described by the Hurst exponent range $(0.5; 1>$. In this case the data is more stable and tends to maintain its trend (increase or decrease) for longer period of time. This adds up to the already mentioned "smoothness" or lack of roughness. Based on Eq. (3) it's easy to notice that boundary values 0 and 1 result in non-fractional dimension. Approaching 0 means an increase of roughness which in the border case results in filling the entire plane, creating an object that is 2-dimensional. Extreme persistence will create a straight line and result in a 1-dimensional object. The last special value, which is often referred as theoretical, is Hurst exponent equal 0.5, which is characterized by complete randomness, lack of correlation between consecutive steps and is a realization of a Brownian motion (Fig. 2 middle plot).

The one of the oldest ways to estimate the Hurst exponent [13] is to calculate it as the function of the Pearson's correlation coefficient (**C**):

$$H = \frac{1}{2}\left(1 + \frac{logC}{log2}\right) \tag{4}$$

Although both parameters (fractal dimension and Hurst exponent) allow to analyze similar object properties, they gave an impulse for future research and development of new methods. Currently, there are many techniques, which can be used to analyze data in different fractional dimensions. Among those methods one could highlight the most popular and significant:

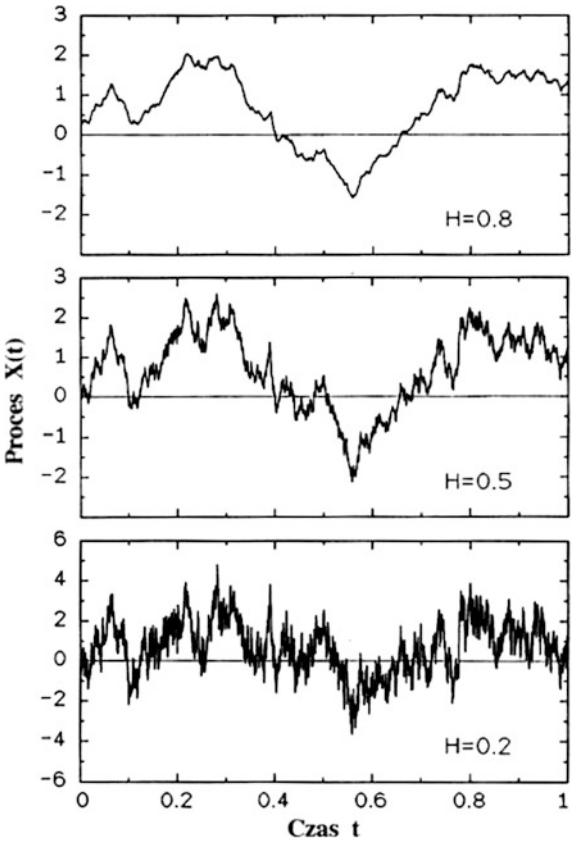

Fig. 2 Realization of the stochastic process for three different values of the Hurst exponent [1]

- R/S (Rescaled Range Analysis) [8],
- DMA (Detrending Moving Analysis) [10, 14],
- DFA (Detrended Fluctuation Analysis) [1],
- MF-DFA (Multifractal Detrended Fluctuation Analysis) [11],
- WTMM (Wavelet Transform Modulus Maxima) [18].

Fractal geometry is not only a theoretical science, it started to be used also during the studies on the phenomena taking place on the financial markets. It's methodologies have started to significantly affect on the perception of capital markets. In new studies one can meet even with the alternative theory for the hypothesis of efficient markets—hypothesis of fractal markets. As it can been seen in Table 1, this theory is closer to the real markets then the efficient market theory.

It's also worth to notice that fractal geometry isn't the only field of science which can be used to analyze capital markets [15]. Special attention should be also paid to log-periodicity [19], theory of thick tails [7], complex systems [6], etc.

Table 1 Comparison of selected properties of the efficient and fractal market hypothesis

Hypothesis of efficient market	Hypothesis of fractal market
• The same time window for all investments • Price are independent • Infinite number of investors • Investors are rational and react immediately to all information • Investor can't influence the price	• Time windows are different and depend on the investor • Price has "long-term memory" • Big but finite number of investors • Investors can decide how to react on obtained information • The price is dependent on the behavior of all investors

2 How to Calculate Hurst Exponent—DMA Method

One of the easiest ways to calculate the value of the Hurst exponent is Detrending Moving Average (DMA) method [14]. Because this method is still quite new (as most of the fractal methods), there are few parameters/limiting conditions which need to be carefully analyzed to better understand their impact. The most important parameters are: the length of analyzed time series (the minimal number of data should be not less than 250), the length of calculated moving average.

The calculation starts with creating a moving average $Y_n(i)$ of length n in point i for the analyzed time series $y(i)$ of length N:

$$Y_n(i) = \frac{1}{n}\sum_{k=0}^{n} y(i-k) \tag{5}$$

The next step is to calculate a modified standard deviation, where in the place of the mean, one should use a moving average from first step (Eq. 5):

$$\sigma_{DMA}(n) = \sqrt{\frac{1}{N-n}\sum_{i=n}^{N}\left[y(i) - Y_n(i)\right]^2} \tag{6}$$

The last step of this method is to calculate relation between standard deviation calculated in second step (Eq. 6) and the length of analyzed moving average n:

$$\sigma_{DMA}(n) \sim n^H \tag{7}$$

Evaluating the modified standard deviation has to be done multiple times for different values of n (length of the moving average) in order to be able to determine the Hurst exponent. The number of repetitions is not strictly specified, but the more data points are used for the final estimation of (Eq. 7) the more exact value of Hurst exponent will be (Fig. 3).

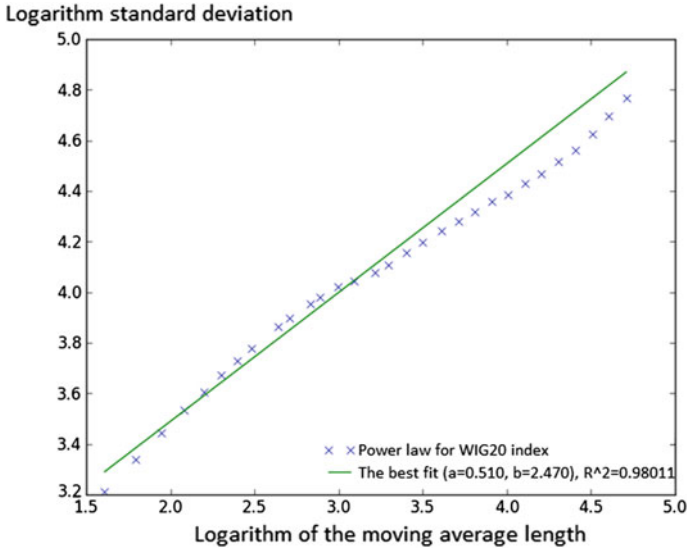

Fig. 3 Example of a graph which shows the dependence between standard deviation (axis OX) and the length of moving average (axis OY). Own work

The easiest way to find the value of Hurst exponent is to create log-log plot of calculated vales (standard deviation and length of moving average). This allows to obtain the Hurst exponent with the use of simple fitting a linear function to the available data.

3 Analysis of the Hurst Exponent

The analysis was done for the index WIG20 from Warsaw Stock Exchange (WIG), for different date and length of the data sets. All calculation was done on returns from prices of the analyzed index.

In first case, the calculation was taken for time span from 1997.07.01 to 1999.04.01. For this period the value of Hurst exponent is equal to 0.585, which defines data as persistent. Figure 4 shows that the analyzed data are relatively stable, with some fluctuation at the end of period.

Table 2 shows the results of the Hurst exponent, which was calculated for different length of time series. The period including only first 250 data is characterized by stability, which is reflected in value of the Hurst exponent—0.613. It's worth to notice that starting from 350 data, the calculation shows the same value.

The second case is an analysis of a time series from 2003.08.01 to 2005.04.28. For this interval the value of the Hurst exponent is equal 0.510, which characterizes

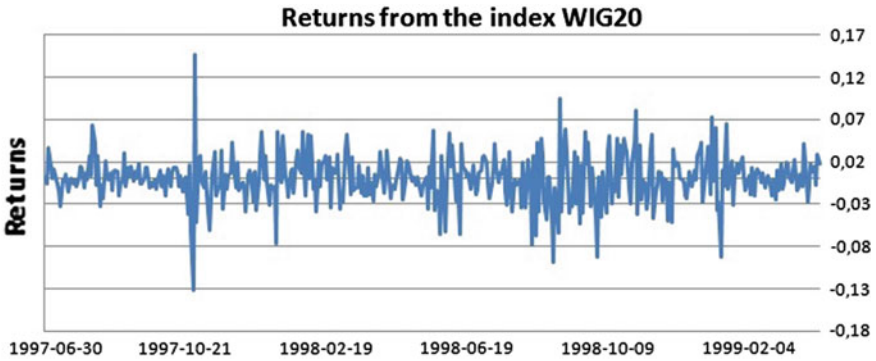

Fig. 4 Plot of the returns from the index WIG20. Data from 1997-07-01 to 1999-04-01. Own work

Table 2 Results of the Hurst exponent for different lengths of time series. Own work

Date	Hurst exponent
1997.07.01–1998.07.03 (250 data)	0.613
1997.07.01–1998.09.11 (300 data)	0.591
1997.07.01–1998.11.04 (350 data)	0.585
1997.07.01–1999.02.04 (400 data)	0.585
1997.07.01–1999.04.01 (440 data)	0.585

Table 3 Results of the Hurst exponent for different lengths of time series. Own work

Date	Hurst exponent
2003.08.01–2004.07.29 (250 data)	0.458
2003.08.01–2004.10.07 (300 data)	0.440
2003.08.01–2004.12.20 (350 data)	0.476
2003.08.01–2005.02.28 (400 data)	0.473
2003.08.01–2005.04.28 (440 data)	0.510

slightly persistent data. In contrast to first case, this time the data fluctuates more, especial at the beginning (Table 3).

As it could be expected the Hurst exponent value for the first 250 data are bellow value 0.5. It's means that the data are antipersistent, and they have a tendency to change their direction. After December 2004 the Hurst value starts to grow, which can be seen as the data stabilization—shows on Fig. 5.

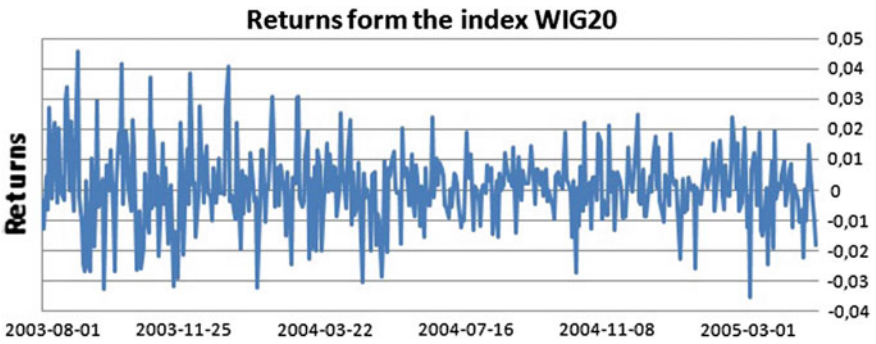

Fig. 5 Plot of the returns from the index WIG20. Data from 2003.08.01 to 2005-04-28. Own work

4 Conclusion

Most of the works about Hurst exponent show it as a simple (single value), which can be used to characterise large amounts of data. This way of using this parameter (i.e. single value to describe the entire data series) didn't give too much information about the past and probable future behaviour of the analyzed data. However, small sets of Hurst exponent values can show possible future changes as their variations reflect a change in the system. For example, when the data is persistent and the Hurst exponent value decreases, there is an increased probability (which is increasing when the H value decreases) that the trend of the data will change.

It's worth to notice that the Hurst exponent is a tool, which can't be used for all data sets. First of all, this parameter can be estimated only for big data sets (at least 250 data). Secondly, occurrence of extreme events (huge drops or increases) may cause the method to be inaccurate (as with any other numerical method). Thirdly, it requires proper calculation of the H exponent via the linear fit which is often forgotten and if it the fit is poor it will lead to unreliable results.

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State-Space Modeling and Analysis of Order-up-to Goods Distribution Networks with Variable Demand and Positive Lead Time

Przemysław Ignaciuk

Abstract The paper addresses inventory management problem in goods distribution systems organized in a network structure. Contrary to majority of earlier approaches, that restrict the analysis to chain and tree-like configurations, mesh connectivity is considered. The external, a priori unknown demand may be imposed on any node of the managed network and goods trans-shipments are effectuated with positive lead time. The paper proposes a state-space model of the network node interaction under distributed order-up-to inventory policy. Managerial insights regarding target stock and warehouse space selection are provided and supported with numerical tests.

Keywords Inventory management · Logistic networks · Time-delay systems · Discrete time systems

1 Introduction

Owing to difficulties, both in formal and numerical analysis, the research work in the area of goods distribution system control and optimization has been limited mainly to basic configurations. Various authors analyzed the performance of classical inventory management strategies in the single stage [1, 2], serial [3, 4], or tree-like set-ups [5, 6]. Nowadays, widely deployed information handling systems and efficient communication solutions allow for exercising performance adjustments in more elaborate architectures.

In this work, the goods distribution network under consideration is allowed to have mesh topology. The stock review and order placement occur at regular time intervals in a periodic-review framework. The orders are realized with non-negligible lead-time delay, different at various node links. A mathematical

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model of node interactions is constructed and used to study the system performance under the classical order-up-to (OUT) inventory policy. The policy is implemented in a distributed way so that the stock replenishment orders in response to the external (and internal) demand are generated based on locally accessible information only. The external demand is a priori unknown—the model accepts any stochastic or deterministic function typically considered in inventory control problems. Excess demand is lost which introduces extra non-linearity into the system dynamic representation. By generating always non-negative and bounded ordering signal and finite stock level, the OUT policy is demonstrated robust to demand uncertainty. Reference stock level selection is discussed in view of maximizing demand satisfaction.

2 System Dynamics

2.1 Model of Entity Interaction

The goods distribution network to be controlled consists of N nodes with the indices taken from the set $\Omega_N = \{1, 2, \ldots, N\}$. The stock inside the network is refilled from $M - N$, $M \geq N$, external sources. The set of all node indices, including the controlled nodes and external sources, is denoted by $\Omega_M = \{1, 2, \ldots, M\}$.

Let $x_i(k)$ represent the on-hand stock (readily available resources) at node i, $i \in \Omega_N$, in period k, $k = 0, 1, 2,\ldots$, and $d_i(k)$ is the exogenous demand imposed on that node from outside the controlled network. The sequence of events at controlled node i in period k is as follows:

1. The record of current on-hand stock $x_i(k)$ and external demand $d_i(k)$ is obtained.
2. The received shipments are registered into the on-hand stock.
3. The inventory management system attempts to fulfill the external demand from the on-hand stock. Excess demand is lost, i.e. the external customers are considered impatient and realize purchases elsewhere if they do not find enough resources at node i.
4. The inventory management system gathers internal requests (goods ordered from other nodes within the controlled network).
5. The system attempts to satisfy the internal requests according to the goods availability after fulfilling the external demand. In case of deficit, the requests are decreased in proportion to the ordered quantity, e.g. if the deficit amounts to *def* then the orders, say u_1 and u_2, are reduced to $u_1(1 - def/(u_1 + u_2))$ and $u_2(1 - def/(u_1 + u_2))$, respectively.
6. Goods are sent inside the controlled network according to the updated requests.

The on-hand stock at a node is used to respond to the external demand imposed at that node and internal traffic needs. The external demand may be placed at any node in the network (not just selected contact points), which complicates the model

but closely reflects the actual real-life settings [7]. Answering the external requests (demand) takes precedence over the internal goods traffic.

The external demand is modeled as an uncertain, time-varying, bounded function of time $0 \leq d_i(k) \leq d_i^{\max}$, where $d_i^{\max} \geq 0$ denotes the upper estimate of $d_i(k)$. No assumption is taken regarding the nature of the stochastic or deterministic process describing evolution of d_i (see e.g. [8] for the rationale behind this type of demand representation in robust inventory control framework).

Denoting the goods quantity received by node i in period k by $Q_i^R(k)$ and the shipments sent by that node towards other nodes inside the controlled network by $Q_i^S(k)$, the stock balance equation may be represented as

$$x_i(k+1) = \left(x_i(k) + Q_i^R(k) - d_i(k)\right)^+ - Q_i^S(k), \tag{1}$$

where $(\xi)^+ = \max\{\xi, 0\}$ is a saturation function. Introducing a variable $-h_i(k)$—to denote the actually realized demand by node i in period k,

$$h_i(k) = \min\{x_i(k) + Q_i^R(k), d_i(k)\}, \tag{2}$$

relation (1) simplifies to

$$x_i(k+1) = x_i(k) + Q_i^R(k) - h_i(k) - Q_i^S(k). \tag{3}$$

Let the overall order issued by node i in period k for its suppliers (other nodes inside the network or external sources) be denoted by $u_i(k)$ and the fraction requested from supplier j, $j \in \Omega_M$, by $\alpha_{ji}(k) \in [0, 1]$. Then,

$$Q_i^S(k) = \sum_{j \in \Omega_N} \alpha_{ij}(k) u_j(k). \tag{4}$$

The goods are delivered with non-negligible lead-time delay, comprising all the activities related to document handling, shipment preparation, and transportation. Denoting lead time on the connection between supplier j and node i by L_{ji}, $L_{ji} \in \{1, 2, \ldots, L\}$ with L the maximum delay in goods provision between any two neighboring nodes, one has

$$Q_i^R(k) = \sum_{j \in \Omega_M} \alpha_{ji}(k - L_{ji}) u_i(k - L_{ji}). \tag{5}$$

Initially, there are no goods in transit, i.e. $u_i(k) = 0$ and $\alpha_{ji}(k) = 0$ for $k < 0$.

Without loss of generality the network is assumed connected, i.e. there is no isolated node and there exists a path from at least one external source to each node. It is also assumed directed in the sense that if $\alpha_{ji}(k) \neq 0$, then $\alpha_{ij}(k) = 0$ for i, $j \in \Omega_N$. Moreover, for any $i \in \Omega_N$, $\alpha_{ii}(k) = 0$, so that no controlled node is a source of goods for itself. Full order partitioning is attempted according to nominal weights

α_{ij} and if not possible (owing to resource deficit at the suppliers) the weights are appropriately decreased as stipulated in step 5 above, which implies

$$\underset{i\in\Omega_N}{\forall}\ 0 \le \sum_{j\in\Omega_M} \alpha_{ji}(k) \le 1. \tag{6}$$

when supplier j has enough resources to respond to the request placed by node i, $\alpha_{ij}(k) = \alpha_{ij}$. Otherwise, the supplier experiences resource starvation and $\alpha_{ij}(k) < \alpha_{ij}$. The external sources are not subject to capacity restriction, thus they never experience starvation. Since backorders are not allowed, partitioning strategy (6) makes $x_i(k) \geq 0$.

2.2 State-Space Description

In order to study the system properties from networked perspective, it is convenient to describe the model in a state space. The following state-space representation is proposed

$$\mathbf{x}(k+1) = \mathbf{x}(k) + \sum_{j=1}^{L} \mathbf{B}_j(k-j)\mathbf{u}(k-j) + \mathbf{B}_0(k)\mathbf{u}(k) - \mathbf{h}(k), \tag{7}$$

where:

- $\mathbf{x}(t) = [x_1(t) \ldots\ x_N(t)]^T$ is the vector of on-hand stock levels inside the controlled network;
- $\mathbf{u}(t) = [u_1(t) \ldots\ u_N(t)]^T$ is the vector of stock replenishment signals generated by the network nodes;
- $\mathbf{h}(t) = [h_1(t) \ldots\ h_N(t)]^T$ is the vector of realized demands with $\mathbf{d_{max}} = [d_1^{\max} \ldots\ d_N^{\max}]^T$ grouping the information about the demand upper bounds;
- diagonal matrices

$$\mathbf{B}_j(k) = \begin{bmatrix} \sum\limits_{i:L_{i1}=j} \alpha_{i1}(k) & 0 & 0 & \ldots & 0 \\ 0 & \sum\limits_{i:L_{i2}=j} \alpha_{i2}(k) & 0 & \ldots & 0 \\ 0 & 0 & \sum\limits_{i:L_{i3}=j} \alpha_{i3}(k) & \ddots & \vdots \\ \vdots & \vdots & \ddots & \ddots & 0 \\ 0 & 0 & 0 & \ldots & \sum\limits_{i:L_{iN}=j} \alpha_{iN}(k) \end{bmatrix} \tag{8}$$

for $j = 1,\ldots, L$, $i \in \Omega_M$, hold the information about the node interconnections and goods acquisition with lead time j (incoming shipments);

- matrix

$$\mathbf{B}_0(k) = -\begin{bmatrix} 0 & \alpha_{12}(k) & \alpha_{13}(k) & \dots & \alpha_{1N}(k) \\ \alpha_{21}(k) & 0 & \alpha_{23}(k) & \dots & \alpha_{2N}(k) \\ \alpha_{31}(k) & \alpha_{32}(k) & 0 & \ddots & \vdots \\ \vdots & \vdots & \ddots & \ddots & \alpha_{N-1,N}(k) \\ \alpha_{N1}(k) & \alpha_{N2}(k) & \alpha_{N3}(k) & \dots & 0 \end{bmatrix} \tag{9}$$

corresponds to the shipments sent inside the network.

With zero initial input, $\mathbf{u}(k) = 0$ for $k < 0$, using relation (7), the stock level in any period $k > 0$ may be determined from

$$\begin{aligned} \mathbf{x}(k) &= \mathbf{x}(0) + \sum_{i=0}^{L} \sum_{j=0}^{k-1} \mathbf{B}_i(j-i)\mathbf{u}(j-i) - \sum_{j=0}^{k-1} \mathbf{h}(j) \\ &= \mathbf{x}(0) + \sum_{i=0}^{L} \sum_{j=0}^{k-i-1} \mathbf{B}_i(j)\mathbf{u}(j) - \sum_{j=0}^{k-1} \mathbf{h}(j). \end{aligned} \tag{10}$$

For further analysis, it is also convenient to define

$$\mathbf{B} = \sum_{j=0}^{L} \mathbf{B}_j, \tag{11}$$

where the time reference is dropped to reflect the nominal case of internal traffic without goods starvation at the nodes.

Lemma 1 *The inverse of* $\boldsymbol{B}$ *defined by* (11) *is a positive matrix.*

Proof One needs to show that all the entries of $\mathbf{B}^{-1}$ are non-negative. It follows from (6), (8), and (9) that when starvation does not occur

$$\mathbf{B} = \mathbf{I} + \mathbf{B}_0, \tag{12}$$

where $\mathbf{I}$ denotes an $N \times N$ identity matrix and $\mathbf{B}_0$ is a hollow matrix with entries $-\alpha_{ij} \in [-1, 0]$, column-wise summing at most to -1. Moreover, since the network is directed $\alpha_{ij} \neq 0$ implies $\alpha_{ji} = 0$, which means that all the leading principal minors and the determinant of $\mathbf{B}$ equal 1. Hence, applying the Sylvester's criterion [9. p. 404], one may conclude that $\mathbf{B}$ is positive definite and thus invertible. Therefore, since $\|\mathbf{B}_0\| < 1$, where $\|\cdot\|$ denotes induced norm for matrices and Euclidean norm for vectors, one can represent $\mathbf{B}^{-1}$ as a series,

$$\mathbf{B}^{-1} = (\mathbf{I} - (-\mathbf{B}_0))^{-1} = \mathbf{I} + (-\mathbf{B}_0) + (-\mathbf{B}_0)^2 + \cdots \tag{13}$$

Consequently, since all the entries of $-\mathbf{B}_0$ are non-negative, $\mathbf{B}^{-1}$ is also positive. □

3 Inventory Management Strategy

3.1 Order-up-to Inventory Management

In order to replenish the stock depleted to satisfy the external market demand and internal goods requests imposed at a network node, one can apply the OUT policy. The OUT policy says to bring the on-hand stock up to a reference level if the sum of already stored goods and goods in-transit falls below that reference. When forecasts of future demand evolution are not used, the OUT policy calculates the order quantity according to (see e.g. [10] for an extensive treatment of various fundamental ordering strategies):

$$u_i(k) = x_i^{ref} - x_i(k) - OR_i(k), \tag{14}$$

where x_i^{ref} denotes the reference (order-up-to) level and $OR_i(k)$ is the open-order quantity, i.e. the amount of goods already ordered at the suppliers but not yet received due to lead time.

The open-order quantity constitutes the accumulated difference between the requested and received goods quantity. Considering the lead-time delay in goods acquisition, possibly different at each interconnection, it may be determined as

$$\begin{aligned} OR_i(k) &= \sum_{j\in\Omega_M}\sum_{t=0}^{k-1}\alpha_{ji}(t)u_i(t) - \sum_{t=0}^{k-1}Q_i^R(t) \\ &= \sum_{j\in\Omega_M}\sum_{t=0}^{k-1}\alpha_{ji}(t)u_i(t) - \sum_{j\in\Omega_M}\sum_{t=0}^{k-1}\alpha_{ji}(t-L_{ji})u_i(t-L_{ji}), \end{aligned} \tag{15}$$

and taking into account zero initial input,

$$OR_i(k) = \sum_{j\in\Omega_M}\sum_{t=0}^{k-1}\alpha_{ji}(t)u_i(t) - \sum_{j\in\Omega_M}\sum_{t=0}^{k-L_{ji}-1}\alpha_{ji}(t)u_i(t) = \sum_{j\in\Omega_M}\sum_{t=k-L_{ji}}^{k-1}\alpha_{ji}(t)u_i(t). \tag{16}$$

3.2 OUT Policy in Vector Form

Note that classical OUT policy (14) establishes the replenishment signal using locally accessible information only. Hence, it can be deployed as a fully distributed strategy, operating independently at each node. In order to evaluate its properties from the network system perspective, without changing its distributed character, the policy will be written in a vector form.

Let $\mathbf{x_{OUT}} = [x_1^{ref} \ldots x_N^{ref}]^T$ denote the vector of reference inventory levels. Using (7)–(9), the OUT policy for the analyzed goods distribution network can be represented in vector form as

$$\begin{aligned}\mathbf{u}(k) &= \mathbf{x_{OUT}} - \mathbf{x}(k) - \sum_{i=1}^{L}\sum_{j=i}^{L}\mathbf{B}_j(k-i)\mathbf{u}(k-i) \\ &= \mathbf{x_{OUT}} - \mathbf{x}(k) - \sum_{i=1}^{L}\sum_{j=k-i}^{k-1}\mathbf{B}_i(j)\mathbf{u}(j).\end{aligned} \tag{17}$$

4 Property Analysis

4.1 Ordering Signal

At the initial time, $\mathbf{u}(0) = \mathbf{x_{OUT}} - \mathbf{x}(0)$, which implies that $\mathbf{x_{OUT}}$ must be chosen at least equal to $\mathbf{x}(0)$ to avoid negative order. For $k > 0$ the ordering signal satisfies the condition specified in the following theorem.

Theorem 2 *For $k > 0$ the stock replenishment signal established according to (17) for system (7) is non-negative and bounded.*

Proof Substituting (10) into (17), results in

$$\mathbf{u}(k) = \mathbf{x_{OUT}} - \mathbf{x}(0) - \sum_{i=0}^{L}\sum_{j=0}^{k-1}\mathbf{B}_i(j)\mathbf{u}(j) + \sum_{j=0}^{k-1}\mathbf{h}(j) \tag{18}$$

(the term $\sum_{j=k}^{k-1}\mathbf{B}_0(j)\mathbf{u}(j) = 0$ has been included for notational brevity). Then, using (18), $\mathbf{u}(k+1)$ can be expressed as

$$\begin{aligned}\mathbf{u}(k+1) &= \mathbf{x_{OUT}} - \mathbf{x}(0) - \sum_{i=0}^{L}\sum_{j=0}^{k}\mathbf{B}_i(j)\mathbf{u}(j) + \sum_{j=0}^{k}\mathbf{h}(j) \\ &= \mathbf{x_{OUT}} - \mathbf{x}(0) - \sum_{i=0}^{L}\sum_{j=0}^{k-1}\mathbf{B}_i(j)\mathbf{u}(j) + \sum_{j=0}^{k-1}\mathbf{h}(j) - \sum_{i=0}^{L}\mathbf{B}_i(k)\mathbf{u}(k) + \mathbf{h}(k) \\ &= \mathbf{u}(k) - \sum_{i=0}^{L}\mathbf{B}_i(k)\mathbf{u}(k) + \mathbf{h}(k) = \left[\mathbf{I} - \sum_{i=0}^{L}\mathbf{B}_i(k)\right]\mathbf{u}(k) + \mathbf{h}(k).\end{aligned} \tag{19}$$

It follows from (6) that

$$\mathbf{I} - \sum_{i=0}^{L} \mathbf{B}_i(k) = \mathbf{I} - \sum_{i=1}^{L} \mathbf{B}_i(k) - \mathbf{B}_0(k) \succ = \mathbf{I} - \mathbf{I} - \mathbf{B}_0(k) = -\mathbf{B}_0(k), \tag{20}$$

where "$\succ =$" denotes positive semi-definite relationship between matrices and "$\geq$" represents component-wise inequality. Since at any k, $-\mathbf{B}_0(k)$ is a positive matrix and realized demand $\mathbf{h}(k)$ is non-negative, the ordering signal is non-negative as well. Moreover, since $||\mathbf{I} - \sum_{i=0}^{L} \mathbf{B}_i(k)|| < 1$ (see the reasoning in the proof of Lemma 1), (19) represents an asymptotically stable linear system with input $\mathbf{h}(k)$. Consequently, since $\mathbf{h}(k) \leq \mathbf{d}(k) \leq \mathbf{d}_{\max}$, $\mathbf{u}(k)$ is bounded for any bounded demand. □

Theorem 2 shows that the classical ordering policy generates a feasible ordering signal when implemented in a distributed way in the analyzed networked distribution system.

4.2 Reference Stock Level Selection

Modern goods distribution systems and supply networks are expected to provide a high degree of customer satisfaction—a high service level. Following a common practice, in this work the fill rate, i.e. the fraction of external demand satisfied from the resources available at the nodes, is chosen as a measure of obtained service level. The fill rate is influenced by the selection of reference stock level. Due to the overall complexity implied by the networked system architecture, the optimal reference $\mathbf{x}_{\mathbf{OUT}}$ ought to be determined through numerical computations for a given connectivity configuration and type of demand. Below, an intuitive procedure to determine $\mathbf{x}_{\mathbf{OUT}}$ for avoiding stock-out and thus obtaining high fill rate is presented. The procedure assumes that the inventory manager possesses only the knowledge about the demand upper bound $\mathbf{d}_{\max}$. Neither the type of demand distribution, nor its statistical parameters, are required.

Using (19), steady-state replenishment signal $\mathbf{u}_{\mathbf{ss}}$ in response to steady-state demand $\mathbf{d}_{\mathbf{ss}}$ is determined as

$$\mathbf{u}_{\mathbf{ss}} = \left(\mathbf{I} - \sum_{i=0}^{L} \mathbf{B}_i^{\mathbf{ss}}\right)\mathbf{u}_{\mathbf{ss}} + \mathbf{d}_{\mathbf{ss}} = \left(\sum_{i=0}^{L} \mathbf{B}_i^{\mathbf{ss}}\right)^{-1} \mathbf{d}_{\mathbf{ss}}, \tag{21}$$

where $\mathbf{B}_i^{\mathbf{ss}}$ denotes matrix $\mathbf{B}_i(k)$ in steady state.

On the other hand, using (18) and (21), the steady-state stock level is determined as

$$\begin{aligned}\mathbf{x}_{\mathbf{ss}} &= \mathbf{x}_{\mathbf{OUT}} - \mathbf{u}_{\mathbf{ss}} - \sum_{i=1}^{L}\sum_{j=k-i}^{k-1}\mathbf{B}_i^{\mathbf{ss}}\mathbf{u}_{\mathbf{ss}} = \mathbf{x}_{\mathbf{OUT}} - \mathbf{u}_{\mathbf{ss}} - \sum_{i=1}^{L} i\mathbf{B}_i^{\mathbf{ss}}\mathbf{u}_{\mathbf{ss}} \\ &= \mathbf{x}_{\mathbf{OUT}} - \left(\mathbf{I} + \sum_{i=1}^{L} i\mathbf{B}_i^{\mathbf{ss}}\right)\left(\sum_{i=0}^{L}\mathbf{B}_i^{\mathbf{ss}}\right)^{-1}\mathbf{d}_{\mathbf{ss}}.\end{aligned} \tag{22}$$

In the worst case (for maintaining positive stock) $\mathbf{d}_{\mathbf{ss}} = \mathbf{d}_{\mathbf{max}}$ and $\mathbf{B}_i^{\mathbf{ss}} = \mathbf{B}_i$. However, setting the reference stock as

$$\mathbf{x}_{\mathbf{OUT}} > \left(\mathbf{I} + \sum_{i=1}^{L} i\mathbf{B}_i\right)\mathbf{B}^{-1}\mathbf{d}_{\mathbf{max}} \tag{23}$$

results in a desired, positive $\mathbf{x}_{\mathbf{ss}}$.

It follows from (22) that in the absence of demand $\mathbf{x}_{\mathbf{ss}} = \mathbf{x}_{\mathbf{OUT}}$. The numerical analysis presented in the next section indicates that the stock level does not overshoot under the considered policy. It means that assigning storage space at the network nodes equal to $\mathbf{x}_{\mathbf{OUT}}$ suffices to keep all the received goods in a local warehouse. As a result, expensive emergency warehouse space, needed in case of over-stocking, is avoided.

5 Numerical Study

The policy properties will be investigated in the context of the goods distribution network illustrated in Fig. 1. Nodes 1–3 constitute the controlled elements at which the OUT policy is implemented to regulate the stock replenishment process. Nodes 4 and 5 play the role of external sources used to refill the stock inside the network. Nodes 1 and 2, in addition to serving a local market according to demands d_1 and d_2, provide goods for node 3 as intermediate suppliers. Node 3 may be regarded a distribution center for other markets imposing demand d_3. The arrows in the graph indicate the flow of goods. With each node interconnection there is associated a pair of values (α_{ij}, L_{ij}): α_{ij} represents the nominal lot partitioning coefficient, whereas L_{ij} is the delay in procuring orders from node i to j.

The policy performance is verified for the seasonal demand reflecting sudden changes of customer preferences depicted in Fig. 2. The initial state is assumed equal zero and the order-up to level is set according to (23) for $\mathbf{d}_{\mathbf{max}} = [10\ 15\ 20]^T$ units as $\mathbf{x}_{\mathbf{OUT}} = [108\ 90\ 110]^T$ units. The ordering signal and resulting stock level are shown in Fig. 3. Following the initial phase of stock accumulation, in which not all the customer demand can be satisfied (compare the imposed and realized demand in Fig. 2), the stock level remains positive, even for maximum $\mathbf{d}(k)$. The

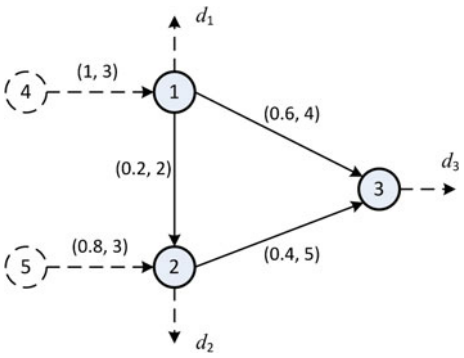

Fig. 1 Goods distribution network

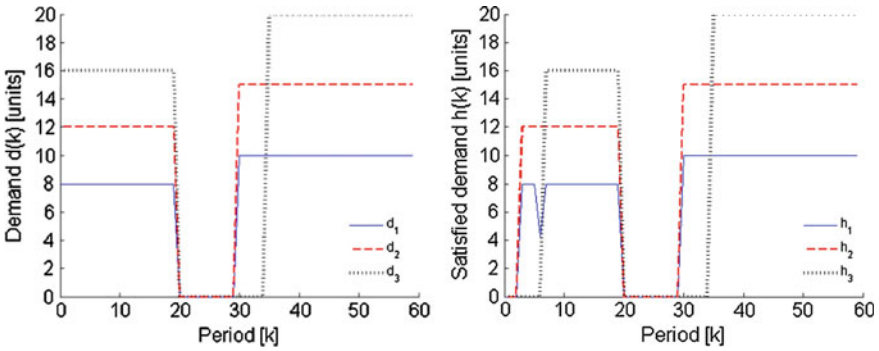

Fig. 2 Imposed (*left*) and realized (*right*) demand

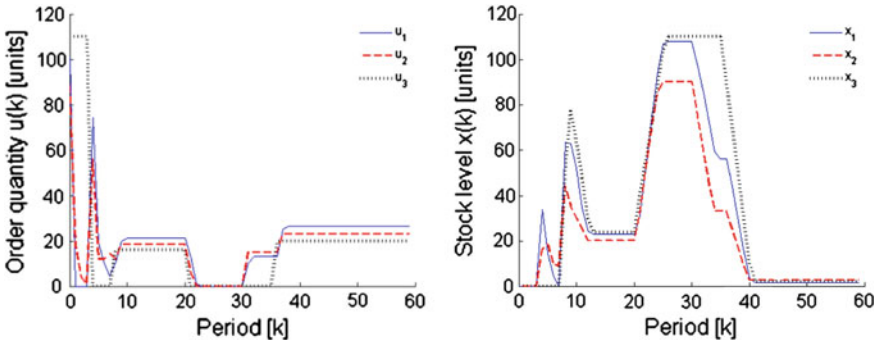

Fig. 3 Orders (*left*) and stock level at the nodes (*right*)

stock never exceeds $\mathbf{x_{OUT}}$. The ordering signal is non-negative and bounded. It closely follows transitions in the market trend without overshoots or oscillations, which indicates possibility of introducing efficient prediction mechanisms.

6 Conclusions

The paper establishes formal grounds for the analysis of the classical OUT policy implemented in a distributed way in logistic networks. The networks are characterized by mesh topology and non-negligible delay on node interconnections. The OUT policy is shown to generate a feasible ordering signal for any bounded demand pattern. Moreover, guidelines of order-up-to level selection for maximizing customer service rate are provided. Since neither orders, nor stock level, exhibit overshoots and oscillations for sudden changes of demand, the bullwhip effect can be avoided. As a result, one may establish cost-efficient relations with external actors.

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Investment Recommendation Optimism—Results of Empirical Research on Polish Capital Market

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Abstract In the article, we analyzed the investment recommendation optimism on polish capital market. We defined the measure of optimism, which compares valuation of companies according to investment recommendation and fixed growth model. Over 170 investment recommendations form years 2014 and 2015 were investigated. The research indicates that the analysts are more likely to announce higher valuation than the historical value drivers and fixed growth model suggests. The highest optimistic perception occurs for companies with low historical financial scores. The highest optimism was observed for companies with "buy" recommendations as well as companies in the value destruction zone.

Keywords Investment recommendation · Valuation · Optimism

1 Introduction

According to the regulation of the Minister of Finance from 19th September 2005 on the information, which forms investment recommendation regarding financial instruments, their issuers or exhibitors [14], the investment recommendations are described as reports, analysis or other information, which recommends, suggests direct or indirect, describes investment behavior regarding one of many investment instruments or issuer of those instruments, included opinions related either to the current or future value or price of financial instruments.

In the long history of capital market, enormous volume of brokerage houses and thousands stock recommendations, which are being issued during the year on the

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world, the investment recommendations surveys have small reference and their history is really short.

The first surveys in that scope were made in United States. In earliest papers based on published analyst forecasts in 1993 [1, 3, 10, 12] based on suggestions from stock recommendations, find that abnormal returns around the announcement cannot be reached. Another research concentrates on comparing group of stock recommendations for one company from different sources. Optimism forecast were measured by comparing the accuracy and optimism of a given analyst's forecast for a particular stock and average optimism for all analysts who make forecast for the same company in comparable forecast horizon. Hong and Kubik [6] analyzed optimism forecast from analyst's carrier perspective and they tried to explain differences between analysts with more experience and analysts just starting their carriers. The authors show that the analys's (accuracy of the analysis) accuracy score for particular analyst has an impact on his carrier, because he is rewarded for generating relative optimistic forecast, by supporting profitable trading strategy of purchasing stocks with the most favorable recommendations. Similar research was realized by Ertimur and others [5] with the sample of 97 thousands of recommendations.

Another strand of literature documents analyst's objectivism and usability of stock recommendations prepared by them. Research regarding optimism among securities analysts has been attributed to incentives provided by investors' skepticism regarding to the reports generated by brokerage houses. Several studies have shown that most of published recommendations are "buy" than "sell" [5]. Morgan and Stocken [11] have devised analyst's objective function, which is able to evaluate if stock price was overvalued and dominated by analyst's lack of objectivity. Jegadeesh et al. [7] have shown, that stock recommendations are mainly prepared for the firms with superior return performance, growing evidence and high stock price, named them as "glamour stocks". Furthermore they show that for eight recommendations, seven have reverse correlation to the value of stock from recommendation with future returns. They show that analysts make favorable reports for some firms and they take company profile with mentioned indicators to the ability of analysts to select superior stocks, where the recommendations are positive. Results of their research show that analyst's recommendations are optimistically biased, especially for stocks, achieving upward trend and showing as "expensive" in the context of firm evaluation, describing analysts more as a "trends hunters" than "information's observers". Such incentives of analysts for those type of firms evaluations are associated with their career concerns, as they think that it will help to develop more quickly their future role. However, this behavior reduces efficiency, as reliable forecast announcement providers for potential investors.

Across the research in the Polish capital market regarding investment recommendations Dąbrowski [4] in his paper analyzed results of investing in stocks, based on portfolio composite from stocks, which had the higher analyst's recommendations. In most of the cases, price of securities did not achieve target price showed in analyst's report—effective price calculation was only in 44.63 %. More than 70 % of announcements recommend purchase of direct stocks though

recommendations were issued in bear trend in stock market, i.e. the market condition in which the prices of securities are falling. Another strand of literature documents overoptimism among analysts. Zaremba and Konieczko [13] tried to measure efficiency of stock recommendations in the Polish capital market, by examining returns, after investing in securities, based on suggestions from stock recommendations. For that purpose in scope of survey were 128 enterprises and final results showed, that stocks, which were evaluated as negative achieved the highest returns. Trading strategy of purchasing (buying long) stocks with the most favorable recommendations by analysts achieved abnormal negative returns. Buzala [1] in survey, which was made in 2008–2005 year time horizon shows that higher information value for stock recommendation was in period till one session from/in the date of announcement and assumes, that more valued from informational perspective proved to be recommendations "sell" than "buy".

In the article, we analyzed the optimism of investment recommendation on polish stock market. The paper is organized as follows. In section Materials and methods we defined the measure of optimism and presented the investigated sample. In section Results detailed outcomes of statistics tests were presented. The conclusions finalize the paper.

2 Methods and Materials

2.1 Measure of Investment Recommendations Optimism

In this paper to define recommendation's optimism we use measure, based on valuation from fixed growth model, according to the equation below:

$$recommendation\ optimism\ indicator = \frac{DCFValuation - FGMValuation}{FGMValuation} \quad (1)$$

where:

- DCFValuation—the value of a company per 1 share with debt included, counted by analyst by discounted cash flow model,
- FGMValuation—the value of a company per 1 share with debt included, counted by fixed growth model for the selected variant.

The point of recommendation's optimism showed by this equation was comparing company value according to fixed growth model with value presented in stock recommendation. High value of this indicator shows that analysts more likely brake the trend based on historical value drivers and prediction of value creation improvement in the analyzed period, than it results from historical data presented in financial statements, which means that the analyst is much more optimistic during

the valuation. When value of the optimism indicator is negative, it can be concluded that company is undervalued in this valuation, thus the optimism indicator closer to zero means that analyst valuation is closer to the generated by fixed growth model valuation.

Company valuation was calculated by fixed growth model developed earlier by us [9]. We consider seven value drivers, i.e. sales growth ratio (sales dynamic), operating margin, productivity of a company's fixed assets, assets usability period, cash conversion cycle, revenues in first year of analyzed period and tax rate, compare [2]. It was presented in detail in paper from 2016 [8].

Analyses were made regarding three types of valuation calculated by fixed growth model summarized below:

1. Valuation based on historical value drivers calculated in a 3 year time horizon before recommendation announcement.
2. Valuation based on historical value drivers calculated in a 1 year time horizon before recommendation announcement.
3. Valuation based on historical value drivers calculated in a 3 year time horizon before recommendation announcement with growth potential included in recommendation.

2.2 Sample Selection

Studies were realized on stock recommendations sample issued by the Polish brokerage houses in 2014–2015 year time horizon. Summary 178 investment recommendations were examined, coming from seven different brokerage houses, on 102 different companies.

The second fundamental sources were the data from companies' financial statement. Data on that scope were form Stockground service provided by Notoria. Consolidated and separated financial statement for 3 year time horizon before recommendation announcement were used. Taking into account necessary information for the value drivers calculation, the resultant matrix contained 5300 of data.

2.3 Research Design

Test procedure set up by us covered the following steps:

- Database preparation
- General analysis of recommendation's optimism
- Detailed analyses of the factors influencing recommendation's optimism

Basic sources of the data were investment recommendation and financial statements. Based on a data from financial statement for particular company, the income valuation model was generated. The model generates data for three different databases corresponded with three groups of analysis presented in Sect. 3.1. Statistical analyses were performed using following steps. The first step was to examine investment recommendation optimism by analysis of data after rejecting extreme observations. First we figure obtained recommendation optimism indicators through the basic statistic calculation. Next we split research sample for 4 groups with the same number of observations and then analyzed obtained values of optimism recommendation in particular quartile. The goal of next survey was to search for indicators that have impact on recommendation optimism. For that purpose we used grouping by quartile and examined whether statistical significance difference exist in those groups for key parameters, which are featuring companies and recommendations. We choose statistical tests based on nature of analyzed variables, which are independent, occur both as quality and quantitative variables and their distribution is not congenial to normal distribution. In that case we reject the analysis of variance ANNOVA, as in few cases completed sample didn't fulfill the necessary assumptions. At the end we choose nonparametric Kruskal–Wallis tests.

3 Results

3.1 Recommendation Optimism

Table 1 presents descriptive statistics for defined investment recommendation optimism. Values were presented for three analyzed samples. The data is presented for data bases with and without extreme observations.

The results suggest that the analysts more likely brake the trend based on historical value drivers and predict improvement of value creation. Skewness of all

Table 1 Descriptive statistics of recommendation optimism indicator

Database	Variable	M	Me	Min	Max	O	SKE	K
1 years	optimism	2.46	0.17	−1.00	143.65	14.43	9.48	93.23
	optimism_WE	1.37	1.05	0.41	4.25	0.96	1.66	2.65
3 years	optimism	2.76	0.57	−0.98	74.26	10.67	5.91	36.02
	optimism_WE	1.64	1.22	0.66	4.02	0.92	1.15	0.12
Growth potential	optimism	2.05	0.82	−0.93	37.98	4.92	4.91	30.07
	optimism_WE	0.99	0.61	−0.93	5.65	1.51	0.97	0.41

Optimism is an optimism recommendation indicator. The rows optimism_WE represents samples after rejecting extreme observations. Symbols for statistics: *M*—Average, *Me*–Median, *Max*—Maximum in sample, *Min*—Minimum in sample, *o*—Standard deviation, *SKE*—Skewness, *K*—Kurtosis

samples shows that most of the observations are located on the right from average value. Furthermore, we see that both the median and the mean are positive, which means that according to DCF valuation from fixed growth model, valuation from DCF from stock recommendation is on average higher. In case of observations without extreme information, the average values for database for 1 and 3 year time horizon from recommendation announcement are higher than 300 % for calculated optimism. Because of most of extreme observations in sample better measure is the median, which also presents values on 100 % of optimism level for those bases after extreme observations rejected.

3.2 Recommendation Optimism Analysis—Quartile Frame

After figure, that recommendation optimism indicator has large differentiation, we decided to split sample by quartiles. Table below presents values of descriptive statistics for particular groups.

For 75 % of observations in almost all databases value of recommendation optimism indicator is positive both for the median and the average. Only for database, where value drivers were calculated for 1 year time horizon, in case of split for data with extreme observations, first and second quartile show the average and the median negative. Based on that, we assume that analysts in their statements are more likely optimistic in income valuation, than historical value drivers suggest (Table 2).

3.3 Analysis of Impacted on Recommendation Optimism Indicators

Further research shows which value driver indicators have impact on analysts' optimism in income valuation. The first part of the study provides a profile of firms, described by value driver indicators that receive overoptimistic or less optimistic recommendations. For that purpose we examined recommendation optimism as a grouping variable and value drivers as multipliers. Additionally we put also other multipliers, which have potentially impact on analyst valuation (Table 3).

The tests show statistically significant differences between companies in quartiles of optimism recommendation for sales growth ratio and operational margin (ROS). The highest level of significance has been noted for 1 year time horizon database between sales dynamics and recommendation optimism in following pairs of quartiles: Q1 and Q3, Q1 and Q4. The same results were obtained was for 3 year

Table 2 Descriptive statistics for quartiles of optimism recommendation indicator

Database	Variable	Q	M	Me	Min	Max	O	SKE	K
1 year	optimism	Q1	−0.62	−0.51	−1.00	−0.33	0.24	−0.28	−1.69
	optimism	Q2	−0.05	−0.06	−0.27	0.17	0.15	0.03	−1.53
	optimism	Q3	0.59	0.52	0.18	1.05	0.30	0.15	−1.52
	optimism	Q4	9.77	2.63	1.10	143.65	27.67	4.89	24.48
	optimism_WE	Q1	0.53	0.50	0.41	0.76	0.13	0.98	−0.39
	optimism_WE	Q2	0.92	0.94	0.79	1.01	0.08	−0.45	−1.11
	optimism_WE	Q3	1.23	1.12	1.05	1.54	0.20	1.11	−0.60
	optimism_WE	Q4	2.65	2.38	1.65	4.25	0.92	1.02	−0.04
3 years	optimism	Q1	−0.47	−0.40	−0.98	−0.10	0.26	−0.61	−0.67
	optimism	Q2	0.24	0.26	−0.04	0.56	0.17	0.08	−1.06
	optimism	Q3	0.96	1.00	0.59	1.25	0.21	−0.44	−1.14
	optimism	Q4	10.14	3.12	1.32	74.26	19.56	2.84	7.22
	optimism_WE	Q1	0.85	0.86	0.66	1.00	0.13	−0.21	−1.78
	optimism_WE	Q2	1.12	1.10	1.03	1.19	0.06	0.05	−1.44
	optimism_WE	Q3	1.55	1.44	1.24	1.99	0.29	0.58	−1.45
	optimism_WE	Q4	3.06	3.12	2.19	4.02	0.55	−0.06	−0.13
Growth potential	optimism	Q1	−0.54	−0.49	−0.93	−0.18	0.26	−0.19	−1.55
	optimism	Q2	0.31	0.36	−0.12	0.71	0.26	−0.23	−1.18
	optimism	Q3	1.39	1.33	0.93	2.02	0.34	0.41	−1.03
	optimism	Q4	6.94	3.87	2.35	37.98	7.90	2.88	9.34
	optimism_WE	Q1	−0.57	−0.55	−0.93	−0.21	0.25	−0.12	−1.62
	optimism_WE	Q2	0.21	0.26	−0.20	0.54	0.25	−0.22	−1.47
	optimism_WE	Q3	1.16	1.13	0.61	1.64	0.32	−0.17	−0.84
	optimism_WE	Q4	3.13	2.99	1.76	5.65	1.05	0.70	−0.16

Optimism is an optimism recommendation indicator. The rows optimism_WE represents samples after rejecting extreme observations. Symbols for statistics: *M*—Average, *Me*—Median, *Max*—Maximum in sample, *Min*—Minimum in sample, *o*—Standard deviation, *SKE*—Skewness, *K*—Kurtosis

time horizon data base. They show, that the stocks with lower historical sale dynamics are more likely to receive more favourable recommendations. High level of significance also shows operational margin and recommendation optimism for the following pairs of quartiles: Q2 and Q3, Q2 and Q4. In 3 year time horizon this significance has been showed also in Q1 and Q3, Q1 and Q4 quartile pairs. It confirmed that analysts are trying to break the historical trend and put a higher valuation for stocks with lower historical returns of sales.

Table 3 The analysis of multipliers in quartiles of optimism recommendation

Variable		Section A: recommendation optimism indicator						Section B: results of range tests					
Quartile		Q1	Q2	Q3	Q4	p-value	K-W test	Q1/Q2	Q1/Q3	Q1/Q4	Q2/Q3	Q2/Q4	Q3/Q4
(a)													
1 year	Sales growth ratio	1.32	1.09	1.06	1.04	0.0002	19.85275		***	***			
	MVCR	5.42 %	5.91 %	5.49 %	6.73 %	0.6854	1.486667						
	No of predicted years	8.73	8.72	8.54	8.70	0.9856	0.1470928						
	FAT	10.97	3.89	9.98	11.46	0.7534	1.198341						
	PV(vR)/EV	0.66	0.58	0.56	0.52	0.2795	3.837716						
	ROS	8.40 %	12.42 %	6.29 %	6.29 %	0.0115	11.03896				**	**	
	ROS-MVCR	0.03	0.07	0.01	0.00	0.0004	18.37075				**	**	
	Depreciation rate	10.38 %	10.50 %	12.48 %	13.82 %	0.6069	1.837065						
	WACC	8.65 %	8.49 %	8.65 %	8.50 %	0.8521	0.7891753						
	CCC	24.67	48.31	54.13	102.45	0.0784	6.805579						
	Valuation/Market price	178.67	1.04	−4.06	0.04	0.0000	91.30026	***	***	***	***	***	
3 years	Sales growth ratio	1.21	1.09	1.16	1.08	0.0094	11.48742		**	**			
	No of predicted years	844.83 %	881.48 %	879.17 %	868.18 %	0.8918	0.6200143						
	FAT	11.39	9.69	7.34	6.78	0.8679	0.7226685						
	PV(vR)/EV	0.55	0.50	0.44	0.43	0.2734	3.891901						
	ROS	11.40 %	11.92 %	2.17 %	2.71 %	0.0001	20.82740		**	***	***	***	
	ROS-MVCR	0.06	0.06	−0.06	−0.02	0.0000	31.96768		***	***	***	***	
	Depreciation rate	12.31 %	11.67 %	10.00 %	14.71 %	0.5019	2.355840						
	WACC	8.77 %	8.46 %	8.29 %	8.63 %	0.6550	1.619346						
	CCC	14.22	95.62	135.78	24.96	0.0007	16.91271	***				**	
	Valuation/Market price	1.10	1.15	1.19	1.14	0.2529	4.080643						

(continued)

Table 3 (continued)

Variable		Section A: recommendation optimism indicator						Section B: results of range tests					
Quartile		Q1	Q2	Q3	Q4	p-value	K-W test	Q1/Q2	Q1/Q3	Q1/Q4	Q2/Q3	Q2/Q4	Q3/Q4
(b)													
Growth potential	Optimism	1.14599	1.06823	1.15475	1.12842	0.2831	3.806516						
	No of predicted years	8	9.38462	8.55556	8.69231	0.0866	6.580174						
	FAT	11.3196	8.50994	8.6457	8.13315	0.6892	1.469935						
	PV(vR)/EV	0.68931	0.57757	0.52978	0.47577	0.1524	5.279752						
	ROS	0.11033	0.09252	0.04218	0.05577	0.1228	5.780564						
	ROS-MVCR	0.05461	0.02998	−0.0174	−0.0046	0.068	7.127089						
	Depreciation rate	0.11042	0.11571	0.11947	0.14083	0.217	4.448010						
	WACC	0.08967	0.08559	0.08277	0.0844	0.0916	6.450760						
	CCC	17.9238	64.2995	65.9453	84.9874	0.0372	8.473097						
	Valuation/Market price	1.22176	1.16339	1.12332	1.07657	0.1079	6.076801						

The table presents results of Kruskal–Wallis test, which determine if there are statistically significant differences between recommendations optimism quartiles, by comparing them with earlier described multipliers. The table can be split into sections: (a) the first one presents the average values of multipliers in particular optimism quartile and p-value indicator and test results, (b) the second presents the statistical differences between optimism quartiles. The means that are significantly different from each other are sign as ***, ** and * for the p-value < 0.01, < 0.05, < 0.1 respectively. Analysed multipliers: Sales growth ratio—sales dynamic, *No of predicted year*—shows number of year used in analyst forecast, *FAT*—fixed assets productivity, *PV(vR)/EV*—presents proportion of residual present value to enterprise value, *ROS*—returns of sales, which shows operating margin, *ROS–MVCR*—shows surplus of ROS indicator for Minimum Value Creation Rate, *Depreciation rate*—presents rate in percentage at which an asset is depreciated, *WACC*—Weighted average cost of capital, *CCC*—cash conversion cycle, Valuation/Market price—analyst's DCF valuation per 1 share to the share market price ratio

4 Conclusions

Conducted research shows that analysts more likely announce higher valuation than the historical value drivers and fixed growth model suggests. In all of the analyzed databases the average recommendation optimism indicator was positive.

Research shows analysts' tendency for optimistic perception of companies with low historical financial scores. Analysts in their recommendations tried to implement higher recommendation optimism for stocks with lower sales dynamics and operational margin, by prediction of much higher growth in the future, than historical trend suggest. For that purpose "weak" companies achieve the highest recommendation optimism. Additionally "buy" recommendations show definitely higher variability of optimism relative to others announcements.

The research sample contains half of announcements as "buy". Surveys show that "buy" recommendations note higher recommendation optimism indicators than others. After analysis of the recommendation optimism data, based on fixed growth model, it was demonstrated that higher recommendation optimism indicates higher "buy" recommendation probability. The higher recommendation optimism, the more of companies are in value destruction zone. The most of the value destruction companies are in third and fourth quartile of recommendation optimism.

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Intellectual Capital—Measuring the Immeasurable and Reporting

Anna Maria Kamińska, Agnieszka Parkitna and Sandra Siałkowska

Abstract This paper reviews "Reporting of intellectual capital." This dissertation shows the problem of the definition and the significance of the intellectual capital, as well as the methods and means of measurement and reporting in enterprises. The first part of the work is a query literature on intellectual capital. It presents the origins, definition, nature and the role played by the intellectual capital, as well as various approaches to the subject. The second part describes selected methods of measuring and evaluating the intellectual capital. This section contains information on the preparation of the report and the elements that it should contain in terms of suitability. The last part of paper is a presentation of a proposal of the intellectual capital report, that can be developed and used in practice.

Keywords Intellectual capital · Measurement of intellectual capital · Reporting of intellectual capital

1 Introduction

Globalization and open economies as well as the liberalization process enabled increased knowledge acquisition from the world along with its use in the economy. At the end of 20th century a new notion of intellectual capital appeared in the literature. It can be defined in the simplest way as a set of the following compo-

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nents: knowledge, experience, technology, customer relations and skills. It should be noted that the value of modern businesses' intellectual capital exceeds their financial value. In 1997 Ross already distinguished the structural capital that consisted of relations with the environment, organization and development, as well as human capital—competence, attitude, innovation [1]. Along with the increase of the importance of the intellectual capital the need to keep its record increased. It is important that the record is kept in a way that meets the recipients' requirements. It is quite a challenge for the authors preparing reports on intellectual capital. The most significant imponderable was the method of intellectual capital evaluation adopted by a business unit. It is due to a large number of levels or tasks assigned to the intellectual capital. The easiest way to report the intellectual capital is to split it into three components:

- report—is a written statement of facts,
- capital—basically it is a contribution to the development of the company,
- intellect—It is everything we received from the Creator—in the biblical context it can be compared to the parable of the talents. Some people receive one, others two or five talents. The number of talents combined with the invested capital results in the business' success that can be reported [2].

There are numerous evaluation methods than can be found in the literature. However, there is no single ideal one or a standard that would regulate these issues. Some people seek to express the company's intellectual potential in terms of money value, others concentrate primarily on capturing the distinctive factors of the entity that determine its potential for the development. Therefore, one often meets quantitative and qualitative methods of intellectual capital evaluation. Thus, it can be assumed that the intellectual capital presented in the report will show the explanation of the differences between the book and market values [3].

Considering the above, the aim of this article is to conduct and present, as well as analyze the interrelationship of the following ideas: capital, intellect and report, along with an attempt to develop a methodology for reporting of the intellectual capital.

2 The Origins of the Development of the Intellectual Capital

Those managing the knowledge and intellectual capital created a new source of competitive advantage. Since then the company's assets and its value could increase or decrease depending on the way the company create, capture and use their knowledge [4]. A way of thinking also appeared stating that a new type of economy is not only "service economy" but also "knowledge economy." The increasing importance of knowledge in the industry resulted in acknowledgement of the role of "white-collar workers," scientists, engineers, programmers and managers [5].

Intellectual capital plays also a big role in creation the value via R&D tasks. Moreover it can be said, that intellectual capital is a product of combining the R&D with complementary assets, that result in value creation. The relation of intellectual capital and R&D is very strong. The reporting of intellectual capital can strengthen the business recognition by helping to recognize the value constellation of R&D [6]. The value creation capability is highly influenced by human capital [7].

Whereas the intellect, unlike the will or senses are understood as the mind, intellect or intelligence. In other words, it is the total consisting of knowledge experience acquired by a human being, their skills and mental abilities [8]. SEC (Securities and Exchange Commission) Commissioner Wallmanem claims that "the definition of the intellectual capital consists not only of the power of the human mind (intellect + talents) but also of brands and trademarks, as well as the assets entered into the books as historical values [9]".

When looking at companies concentrated on development, one can notice the trend towards more development and the use of intellectual capital. As a part of the essence of the intellectual capital one can distinguish human capital, organizational capital and customer capital (Fig. 1) [10].

The intellectual capital is the knowledge registered by the organization. As a consequence one can distinguish actions aimed at eliminating the organization's weaknesses and directed to establish its value and increase its potential [10]. The lack of a clear definition describing the significance of the intellectual capital in the literature results in the concept being identified and defined in management field as a difference between the market value and the book value of the company. The idea of "the intellectual capital" is often used interchangeably with the idea of "intellectual property," "intellectual assets" and "knowledge assets", where:

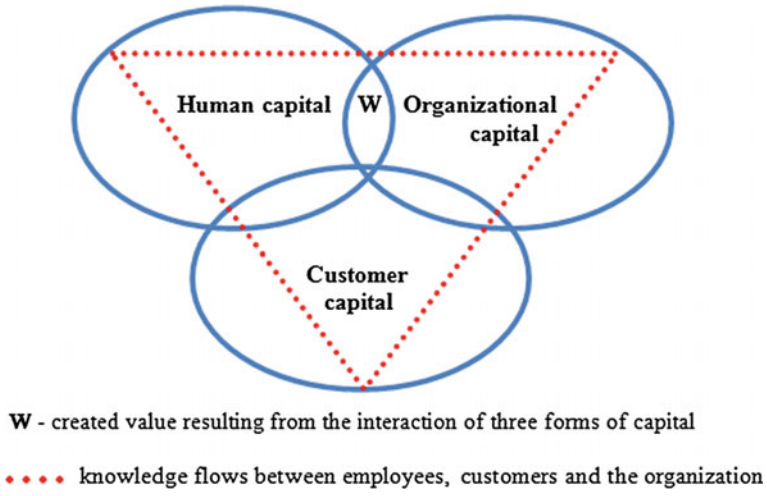

Fig. 1 The model of intellectual capital. *Source* own study based on [10]

- intellectual capital—can be understood as the entire wealth resulting from knowledge (the knowledge itself or a result of its transformation process).
- intellectual property—is an element of the intellectual capital and is legally defined (ownership of patents, trademarks, copyrights).
- intellectual assets, knowledge assets—their definition is vague; this notion is broader than intellectual property.

Thus, the intellectual capital is a non-financial asset reflecting a hidden gap between the market and the book values [13]. It is assumed that the basis of the intellectual capital is the knowledge useful for the company, while simultaneously taking into account communication, intuition, feelings and needs of the employees. This capital constitutes the management skills that utilised in the company's activities are able to generate added value. Skandii wrote down this definition as a mathematical equation assuming that [11]:

$$\textbf{Intellectual capital} = \textbf{human capital} + \textbf{structural capital}$$

The intellectual capital is always associated with knowledge and not necessarily fits the traditional business model, yet it fills the gap between the actual market value of the company and what results from the analysis of the accounting conducted in a traditional manner [12].

3 The Measurement of the Intellectual Capital

It is widely known that if something is of a significant meaning for the company's development, then any leadership's or manager's ambition is to be able to measure the level of its significance. In such a case it will be essential for them to measure the intellectual capital, which is hidden and increases the company's value. One can encounter numerous methods of its measurement in the literature. However, due the complexity and multiplicity of issues related to the subject of the intellectual capital it is difficult to select a single, perfect method for a specific company. All available methods have both advantages and disadvantages. When attempting to decide which method of the intellectual capital measurement would be the best one needs to consider the following factors [13]:

- the recipient of the measurement method is the managing staff,
- the access to the information and its scope,
- the way of acquiring information,
- the cost of acquiring the information.

According to Sopińska two sample methods of the intellectual capital measurement can be distinguished [14]: the technique of the weighted scoring and evaluation profiles.

Guidance for IC Reporting an IC Statement helps overcome the differences in knowledge between entrepreneurs and financiers (information asymmetries) by providing key points and associated narratives which demonstrate that [15]:

- Understands its technologies and areas of expertise—its skills, competencies and capabilities;
- Understands its areas of competitive advantage, its intellectual property (IP) and the technical standards related to its products, processes and markets;
- Understands its customer's needs, wants and aspirations and the value that its products and services are able to deliver to them;
- Understands its markets and how to access them;
- Has a credible strategy for getting its products and services to market, profitably, despite the competition;
- Has a credible strategy for managing everything needed to manage the overall sequence of activities needed to succeed (e.g. value chain positioning and management of operations);
- Is able to substantiate the assumptions used in the preparation of financial projections and is able to provide a flow of information to lenders and investors to keep them informed of the way in which the business is progressing.

An additional method introduced by Danish Trade and Industry Development Council in 1997 is introducing four categories used to measure the intellectual capital [16]:

- the human capital, which consists of work tenure, employees' education and training expenditure;
- the customer capital is defined as a combination of the value of relations with customers, markets and collaborating trades. A reliable assessment of this capital is the number of customers solicited by a given employee. Urbanek relates the customer capital with a notion of non-material organisation resource, which is the total of relations with all current customers [17].
- the technological capital is closely related to expenses for training of a given employee aimed at IT development. It is associated with additional qualifications, certificates and licenses acquired during work tenure.
- processes capital includes determination of costs and employees involved in specific processes. Its measure may be low percentage of downtimes, the work quality as well as the significance and reputation of a given employee in the company.

Measuring the intellectual capital is a difficult and complicated process. It results from the nature of the measured phenomenon—the company's intellectual resources are difficult to grasp, they even happen to be deeply hidden. AS IC has been defined as the combination of the organization's human, organizational and relational resources and their activities [18]. Human capital is the capital, that can't be owned by the company as this is a talent of employees and it leaves the company with them [19].

Relational capital is the value of a firm's relationships with different sites: people and organizations with which it conducts business, external stakeholders, networks with suppliers, distributors, lobby organizations, partners, customer relationships and branding [20].

The measurement of the intellectual capital obviously requires the use of a range of indicators. To measure the customer capital market indicators are used—the quality of customers service, the cost of reaching the target group, consumer behaviors.

The technological capital is measured according to the level of the company's technological advancement, and to measure the processes capital the indicators of quality and efficiency are used. In addition to the relative indicators, in the literature there are also indicators that directly measure the value of the company's intellectual capital. Strassman's formula is one of such methods [21].

$$IC = \frac{\mathbf{IVA}}{Ke} \tag{1}$$

where:

IC - the value of the intellectual capital
IVA - information value added
Ke - the cost of own capital (return on employed capital), and to calculate the value one needs to use the following dependency:

$$\mathbf{IVA} = \mathbf{Zn} - (\mathbf{FAT} * \mathbf{K_d}) \tag{2}$$

where:

Zn - net profit
FAT - the value of financial assets
Kd - cost of debt after tax.

There is also a model that can be used only in case of listed companies and in such a case the total market value added (MVA) is the result of the intellectual capital owned by the company [22]:

$$IC = \frac{\mathbf{MVA}}{WACC} \tag{3}$$

where:

MVA - market value added
WACC - weighted average capital cost.

4 Valuation of the Intellectual Capital

The essence of the intellectual capital measurement is not establishing the indicators alone but their mutual connection, relations and the way they influence one another as well as how they translate onto functioning of the entire organisation. This way the intellectual capital is valuated. Valuation of the intellectual capital means determining its value, which is based on the formal valuation methods. In the literature there are many methods of the intellectual capital valuation. Sveiby proposed one of the divisions, where the valuation methods can be divided into four groups [23].

And the methods that are used the most are some of the four groups distinguished by Sveiby.

Methods based on market capitalisation:

- **MV/BV** (*market-to-book value*)—the indicator of the market value to the book value;
- q-Tobin's Indicator;

Methods based on return on assets:

- **CIV** (*calculated intangible value*);
- **KCE** (*knowledge capital earnings*);
- **VAIC** (*value added intellectual coefficient*)—coefficient of intellectual added value;
- **EVA** (*economic value added*)—economic value added [24].

Methods based on score sheets:

- **Skandia Navigator** [Edvinsson, Malone 2001]
- **Balance Scorecard** [Kaplan, Norton, 1992]
- **National Intellectual Capital Index** [Bontis 2004]
- **Knowledge Audit Cycle** [Schiuma, Marr 2001]

Methods of direct valuation of the intellectual capital:

- **The Value Explorer** [Andriessen, Tissen 2000]
- **Intellectual Asset Valuation** [Sullivan 2000]
- **Total Value Creation** [Anderson, McLean 2000]
- **HR Statements** [Ahonen 1998]

Suggestions of selected measures are presented below. They allow to assess the amount of the intellectual capital as well as valuate it in financial terms.

5 Methods or Reporting the Intellectual Capital in Enterprises

Along with the increase of the importance of the intellectual capital the need to keep its record increased. It is important that the record is kept in a way that meets the recipients' requirements. It is a challenge for the authors preparing reports on the intellectual capital. The most significant imponderable is the method of intellectual capital evaluation adopted by a business unit. It is due to a large number of levels or tasks assigned to the intellectual capital. There are numerous evaluation methods that can be found in the literature. However, there is no single ideal one or a standard that would regulate issues related to the intellectual capital reporting.

It can be said, that IC Reporting is the process of creating the enterprise assets with using intellectual capital to create the value for customers [25].

There can be found two approaches of studying intellectual capital—empirical tests based on financial accounting and practical development and adaption of intellectual capital reports [26].

Some people seek to express the company's intellectual potential in terms of money value, others concentrate primarily on capturing the distinctive factors of the entity that determine its potential for the development. Therefore, one often meets quantitative and qualitative methods of intellectual capital evaluation. Thus, it can be assumed that the intellectual capital presented in the report will show the explanation of the differences between the book and market values. Due to the importance of the differences emerging between two approaches to the company's valuation, more and more units make an effort to create such reports. Developing such a report may answer the needs of the boards and stakeholders [27].

Management & Intellectual Assets has proposed a new model for the voluntary reporting of intellectual assets. In its interim report, the committee specifically states that the goal is to arrive at regulatory disclosure of IC related information. The decision to publish a Japanese model now is motivated by the expectation that this "(…) will have a big impact in the worldwide trend. Also it may be possible to set a de facto standard." (Subcommittee on Management & Intellectual Assets 2005 [28]). Across Europe several guidelines have been developed that offer help on how to draw up an IC Statement. These guidelines are adapted to local circumstances and business culture and differ from one to another with respect to their orientation (internal versus external reporting) and methodology [29].

Looking at current reports it can be said that so far two types of reporting have been developed: non-financial reports including various factors influencing business units, as well as narrative reports. However, most companies that made attempts at reporting their intellectual capital are private entities. The conducted analyses of capital markets show that on the world map of the reporting on the intellectual capital there are some new units appearing that are interested in the subject, yet none of the established approaches has been approved by the international group. Japanese Ministry of Economy, Trade and Industry (METI) has been trying to introduce their method since 2005. The authors of these guidelines

aim at supporting corporate companies in preparing reports on management of the intellectual assets. However, this is still one of the few—along with the Danish one—official initiatives to standardise the methods of reporting on the intellectual capital [30].

6 The Proposal of a General Report on the Intellectual Capital: Wawel S.A. Case Study

The aim of this article is to review available methods, that would measure intellectual capital. As it was said before one of methods is to prepare realistic report that would contain the intellectual capital of the company and provides the reliable data for stakeholders. To show a full picture of the report authors decided to prepare the report based on real company's data.

The research entity is Wawel S.A., one of leading chocolate manufactures in Poland. Time frame of the research are years 2008–2014 and financial reports from that period. In order to prepare the report on the intellectual capital properly one ought to try and find a relevant reflection and follow the steps in the analysed businesses in relation to the report's components [31]:

1. Considering the reasons for preparing the report.
2. Identifying the key groups of stakeholders.
3. Identifying the key value factors.
4. Selecting the key indicators of the method of measure.
5. Measurement and evaluation of the results.
6. Strengthening the effectiveness and usefulness of communication.
7. Obtaining feedback from the stakeholders.
8. Implementing the reporting system on the intellectual capital.

This paper will focus on points 1–5 as 6–8 could be analyzed after implementation of first five points, so implementation of provided report and modification of current accounting policy.

1. **Considering the reasons for preparing the report**

The inspiration to create the report is lack of knowledge in company about intellectual capital. Required is to systemize the knowledge about the intangible assets.

2. **Identifying the key groups of stakeholders**

The stakeholders are those entities, that influence the company and also are under company's impact. There are different types of stakeholders, but the main difference is if the stakeholder is interested how the profit was earned, or if he is just interested in profit.

Based on interviews conducted in Wawel S.A. it looks, that the most important group of stakeholders for company are customers. Of course also very important are investors and shareholders, the same as suppliers. It is known, that without reliable supplier that is providing high quality materials, Wawel S.A. would lose a lot of customers, as would be forced to use worst ingredients.

3. Identifying the key value factors of Wawel S.A.

Nahotko [32] named two types of value factors: material and immaterial. To be able to calculate the company's value it is necessary to use as a support utility company involving the ability to generate income and expenditure which has been incurred for his creation.

On below are shown two very important factors, that are giving a picture of company on the market (Table 1).

As it can be recognized The Gross profit Margin Equity is 27 %—that shows the effectiveness of used capital. The operating profit margin is 19 %, what is a very good value, as in Poland it is about 5–10 %. Indexes above are just an example of indicators with their analysis that can be used in the report.

4. Selecting the key indicators of the method of measure

In case of Wawel S.A. authors decides to show company value as key indicators. To show realistic company value it is necessary to compare company value calculated in different approaches. The table on below contains the company value calculated with use of three well know methods (Table 2).

All methods has advantages and disadvantages. Values shown in the table are divergent. The best would be to use DCF value as this method includes a lot of important factors. This is the most trustful and reliable method.

Table 1 Selected indicators of profitability of Wawel S.A.

		2012			2013		
Gross profit margin equity	Gross profit/own capital	82 710	312 758	0.26	99 804	372 172	0.27
The operating profit margin of the total capital	EBIT/KŁ	77 440	437 625	0.18	96 011	510 542	0.19

Source own research based on http://www.wawel.com.pl (10.05.2015)

Table 2 Value of Wawel S.A.

Method	Company value [PLN]
Market value	1 859 696.2
DCF	622 421
Book value method	268 298

Source own research based on http://www.wawel.com.pl (10.05.2015)

Table 3 VAIC index for Wawel S.A. (2010–2014)

Wawel S.A.	2010	2011	2012	2013	2014
Sales revenue	377 637 000	474 433 000	555 897 000	595 645 000	594 161 000
Operating costs (exc. labor costs)	149 772 000	200 119 000	256 792 000	278 797 000	266 402 000
Added value **(VA)**	227 865 000	274 314 000	299 105 000	316 848 000	327 759 000
Own capital **(CE)**	220 633 000	262 828 000	312 758 000	372 172 000	429 356 000
Efficiency equity **(VACA = VA/CE)**	1.03	1.04	0.96	0.85	0.76
Human capital **(HC)**	43 696 000	51 427 000	56 550 000	60 351 000	61 752 000
The effectiveness of human capital **(VAHU = VA/HC)**	5.21	5.33	5.29	5.25	5.31
Structural capital **(SC = VA-HC)**	184 169 000	222 887 000	242 555 000	256 497 000	266 007 000
The effectiveness of structural capital **(STVA = SC/VA)**	0.81	0.81	0.81	0.81	0.81
Value added intellectual coefficient **(VAIC = VACA + VAHU + STVA)**	**7.06**	**7.19**	**7.06**	**6.91**	**6.88**

Źródło: opracowanie własne na podstawie informacji dostępnych na stronie http://www.wawel.com.pl (10.05.2015)

5. **Measurement and evaluation of the results with using the VAiC method**

As a part of the analysis there was conducted the validation of intellectual capital with using VAIC method. The results can be seen in the table on below (Table 3).

The VAIC index during years 2010–2012 was over 7, that can be a proof of high effectiveness of use of assets and intellectual capital in the process of creation the value of the company. In 2013 there was a decrease in the factor value, but it did impact on the process of value creation.

7 The Proposal of a General Report on the Intellectual Capital in Wawel S.A.

Based on points listed in previous paragraph authors did create a draft of the report on IC for Wawel S.A. The draft on below would need to be extended with using more detailed analysis, but for needs of this paper it was shortened (Table 4).

Table 4 The proposal of a general report on the intellectual capital

Company's name, other details:	**Wawel S.A.,** ul. Władysława Warneńczyka 14, 30-520 Kraków NIP: 676-007-68-68
Type of the report	Internal use
Considering the reasons to prepare the report	The aim of the report for Wawel S.A. is to show the level of intellectual capital in the company. The Result of the report can be very proficient for shareholders and the management of the company, as it can be very supportive in decision making process
Identifying the key groups of stakeholders.	The stakeholders of the report are managers an employees of the company
Identifying the key value factors	Key value indicators • the ability to generate income • material assets • shares in other companies • liabilities; and legal status • innovative capacity and "know – how" • professional employees and management • the strategy of development • good economic condition and profitability
Selecting the key method for the measurement indicators	The intellectual capital of the Company Wawel S.A. It was measured by the • indicator MV/BV and MV–BV • method VAIC The total value of the company was valued • discounted cash flow method (DCF) • the market value
Measurement and evaluating the results	Wawel S.A. will prepare tables and will use graphical methods to show the data and the results of analysis
Strengthening of the effectiveness and usefulness of communication	The results of analysis are going to be validated with professional financial specialists. The aim will be to show reliable data
Getting feedback from the stakeholders	All receivers of the report will be asked for a feedback about the report
Implementing the reporting system on the intellectual capital	The activities related to the intellectual capital need to be monitored. If the initial reports on the Wawel S.A. capital would be successful, then it is worth implementing them and reporting the options for the company's development, which is often determined by the intellectual capital
The stamp and signature	If the board accepts the report they should sign it before it's made public

Source own study based on [31]

Based on the analysis it can be said, that Wawel S.A. have intellectual capital. It could be very helpful if stakeholders would know and use the report above. It would be an effective tool in management of the company. Knowledge about intellectual capital is important in company management and also gives a possibility to build competitive advantage.

8 Conclusions

The aim of this paper was to carry out and present as well analyse the interrelations between the ideas: capital, intellect and report. It was also an attempt to create the form for the report on the intellectual capital in the company.

In order to support it authors collected the most important information related to the contemporary approaches to the intellectual capital from the literature, learnt more about its value as well as selected the best measurements and methods from those available in the literature to analyse a selected company.

The issue of reporting on the intellectual capital is a subject that is more and more often raised by the companies and stakeholders in Poland both in theory and practice. The increased awareness of stakeholders about the importance of the intellectual capital as well as the significant need to keep the record of it results in more companies deciding to implement such reports in their accounting policy. Such a report becomes a source of essential information to potential investors helping make a decision whether to invest in the purchase of shares of a given company or not.

The article is an attempt to systematise the methodology for the reporting on the intellectual capital considering the lack of one, generally adopted method of recognising the intellectual capital, and those existing ones contain a lot of unknown and are not easy for a practical verification. Those attempts often happen to be innovative.

The case study in the article was an attempt to creating reliable report of intellectual capital in the company. Authors did systemize information provided by Wawel S.A. company and showed shorten form of the report.

To sum up, having acquired the information from the literature and analysed annual reports and financial statements it can be said that the report on the intellectual capital developed according to the presented guidelines may help obtain the knowledge needed by the stakeholders, which also means completing the established goals. The information presented in the reports following specific principles (principles developed on the basis of the details analyses) become a more effective tool to allow the company's board, the external stakeholders and potential investors to make decisions.

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Part II
Management of Innovation

Open Innovation Model in Enterprises of the SME Sector—Sources and Barriers

Dominika Mierzwa, Katarzyna Walecka-Jankowska and Joanna Zimmer

Abstract The objective of the proposed article is identification of sources and barriers affecting the efforts to "open" innovation processes in Polish organizations. It presents the results of empirical research conducted through a survey on 83 Polish companies from the SME sector. The concept of open innovation, as a new paradigm of innovation management, was first used by Chesbrough (2003).

Keywords Open innovation · Barriers · Source · SME sector

1 Introduction

Dynamic changes in today's economy, connected to growing competition, diffusion of knowledge, high investment outlays for research and development as well as shortening product life cycles, create the need for enterprises to intensify their use of external sources of innovation [1, 2–4], [5, 6, 7]. Innovation is considered one of the main determining factors of competitiveness in business based on knowledge [4, 8, 9]. Modern organization's begin to incorporate knowledge, ideas and experiences of their clients, suppliers and strategic partners into their internal innovation processed to a greater extent. Such activities are commonly known as open innovations [4]. Innovation may also be generated by way of international collaboration between companies, which means that the issue at hand is vital not only at the level of the organization itself, but also at the regional and national level [10].

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The level of interest in open innovation is growing constantly around the world, including Poland [6, 8, 9]. The growth in popularity of open innovation as a new paradigm of innovation management raises a question: are companies from the SME (Small and Medium Enterprises) sector, which comprise nearly 90 % of the Polish market, willing to "open" their innovation processes? In the light of those considerations, the aim of the article is identification of sources and barriers which affect the efforts to "open" innovation processes in Polish companies.

2 Theoretical Basis of Open Innovation

The concept of innovation is based on a flow of knowledge between the organization and its surroundings with the aim to increase the innovation potential of the enterprise and to find outlets for the ideas and technologies that exceed the current business concept.

In this regard, the concept comes down to two basic dimensions:

1. Inflow and outflow of knowledge;
2. Business model;

Chesbrough (2003) stresses that the basic factor for the growth of open innovation in an organization is a significant increase in the number and the level of mobility of knowledge workers [4]. This, in turn, certainly makes it more difficult to control their knowledge and ideas. The concept of open innovation therefore differs from the traditional approach to innovation. The differences are presented in Table 1.

According to the traditional (closed) model of innovation management, enterprises focus mainly on controlling the process of finding and implementing innovation. Organization's generate new ideas through internal R&D activities to subsequently develop those with the highest potential and introduce them to the

Table 1 Comparison between closed and open innovation process in an organization

Category	Closed innovations	Open innovations
Approach to hiring specialist	Hiring the best experts in a given field	Cooperation with specialists from outside the organization
Approach to the first-come, first-served rule	Innovation development process takes place within an organization so that a company could benefit from research	Innovation development process in an organization results from making greater use of external ideas and technologies (know-how)
Approach to competitive	First-come, first-served	Effective business model
Implication of gaining advantage	Most of the best ideas in business sector = victory	The best use of ideas (internal and more importantly—external ones) = win

Source (Barge-Gil 2010, p. 586)

market. This approach requires autonomy, high investment outlays for R&D departments and protection of intellectual property. According to the open innovation model, companies are able to acquire knowledge and commercialize their own ideas through external channels. Ideas which fall outside the current business model of the organization can be made available on the market via license agreements or other arrangements. The sharing of know-how is the basic element which differentiates those two models. In the closed model, organization's conduct long-term research on innovations, incurring high costs, with no guarantee of success. A return on long-term investments can be achieved by selling them.

The idiosyncratic character of open innovation presented in subject literature on management means that research on the nature of this issue is often carried out on multiple levels and with the use of diverse research samples (organizations of various sizes and from various sectors). In vast majority of cases, research focuses on large enterprises from the high-tech, aviation and biopharmaceutical sector [8, 11–14]. However, it is often argued that enterprises operating in the SME sector are also able to benefit from the concept of open innovation [15]. In regard to open innovations, such companies focus mainly on an active search for new technologies, concepts and ideas [16]. Whereas Chesbrough's research (2003) indicates that the "opening" of innovation processes is most often pursued by large organizations. [4]. Similar conclusions can be drawn from the research of Schroll and Mild (2011), which confirms a strong, positive correlation between the size of the organization and the intensification of open innovation [14]. On average, large organizations implement the concept of open innovation 1.5 times more often than companies from the small and medium enterprise sector [17].

3 Open Innovation in the SME Sector—Own Research

On the basis of an overview of subject literature, the authors of the paper established the following objective: identification of sources which generate an impulse to "open" innovation processes as well as barriers inhibiting implementation of the concept. The research was conducted with the use of a survey questionnaire based on 5-point Likert scale. The purpose of the questionnaire was to answer the question of which sources that provide stimulation for using open innovation are most often utilized by organizations from the SME sector and what barriers do such organizations encounter? Moreover, the questionnaire also facilitated analysis of the "openness" of organizations from the SME sector. Their openness in terms of in-novation was determined with a 3-point scale used is the research of Barge-Gil; Celadon [15, 2], namely: closed innovator; hybrid, half-open innovator; open innovator.

The study was conducted among 83 randomly selected, small and medium enter-prises active in various business sectors. The survey questionnaire consisted of three parts plus the respondent's particulars section. The "openness to innovation" indicator was established by taking account of two factors—"input" and

"output" of knowledge (45 determinant analysis). The next part of the questionnaire facilitated determination of the incentives for using the concept of open innovation and inhibitors which obstruct the process of "opening" research and development activities of an organization, which allowed for the analysis of 26 factors.

Due to the sample size, the research should be treated as a pilot study. The level of "openness" of organizations was measured on the basis of subjective opinions of employees of the organizations.

4 Result Analysis

The research carried out suggests that only 8 % of organizations from the SME sec-tor which participated in the study are companies willing to open their research and development processes. The majority of enterprises analyzed (55 %) fall into the category of half-open (hybrid) innovators, which base their innovation-related activity on both external and internal knowledge. Whereas as many as 36 % are organizations closed to innovation, which generate innovation on their own without cooperating with external entities.

Similar results are also found when analyzing organizations according to their size (Fig. 1).

Among small and micro-organizations, the majority are hybrid investors, which inte-grate external knowledge with internal knowledge. Whereas the percentage of open organizations, which treat at least one source of external knowledge as more important than internal knowledge, amounts to 7 %. Among medium enterprises which employ less than 250 workers, as many as 73 % of the study participants are closed innovators, which do not include external sources into their innovation-related activities. Whereas only 27 % are organizations which also benefit from external sources (hybrid and open innovators).

While analyzing determinants that motivate companies from the SME sector (Fig. 2) to open their processes to innovation, answers provided by organizations considered open or hybrid innovators were taken into account.

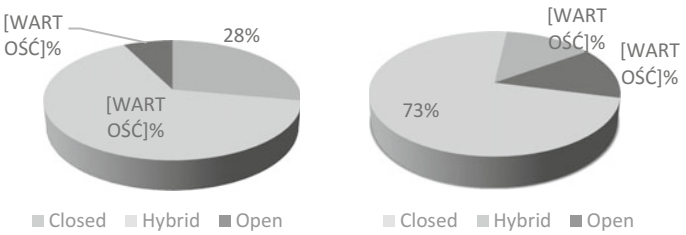

Fig. 1 The approach to the innovation of small and medium-sized organizations (*source* own elaboration)

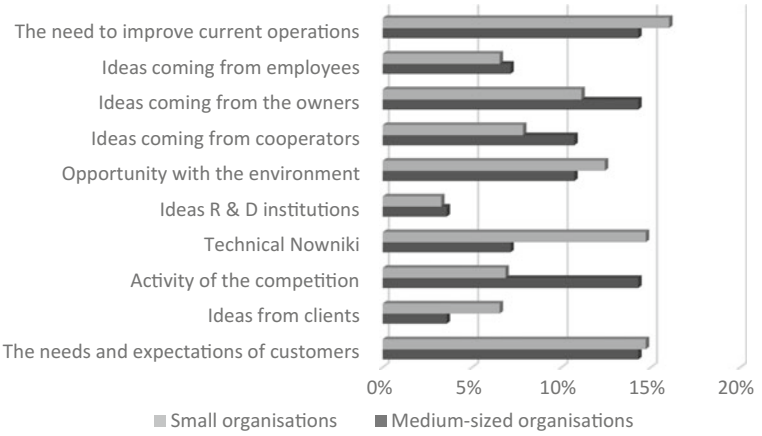

Fig. 2 Sources which stimulate the "opening" of organizations to innovation (*source* own elaboration)

According to the results of the study, the main incentive for micro and small enterprises to search for knowledge outside the company is the need to improve the processes embedded in their daily activity. Other popular incentives include technology-related news published by magazines, patent databases, scientific articles and information found in trade journals. The needs and expectations of clients (15 % of responses) are also significant. The lowest number of responses mentioned ideas and inspirations originating from research and development institutions and universities (only 3 % of responses).

In terms of medium enterprises, the basic source of external knowledge regarding innovation are actions of competitors, needs and expectations of customers, ideas and inspirations of the owners and the need to improve the daily operation of the organization (all with 14 % of responses). For respondents from medium enterprises, research conducted by R&D institutions is also rather insignificant (3 % of responses). Moreover, medium organizations do not treat ideas of their clients as the basic source of innovation (only 4 % of responses).

Barriers which obstruct the use of external knowledge, inspirations and know-how were divided into internal (originating from the organization) and external (originating from the environment) (Figs. 3 and 4). In this respect, answers provided by all enterprises were taken into account, irrespective of their approach to innovation.

The results of the study indicate that the main barrier for small organizations is the financial barrier (costs of acquiring external knowledge, costs of R&D activities and costs related to the development of innovations and their introduction to the market). The least significant factor, according to the respondents, seems to be the

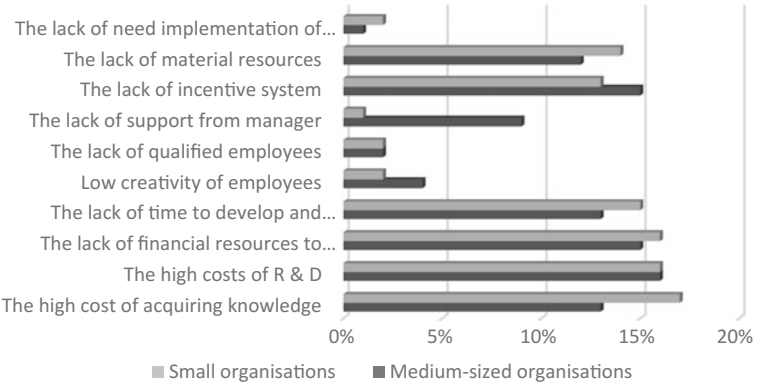

Fig. 3 Internal barriers to the implementation of open innovation (*source* own elaboration)

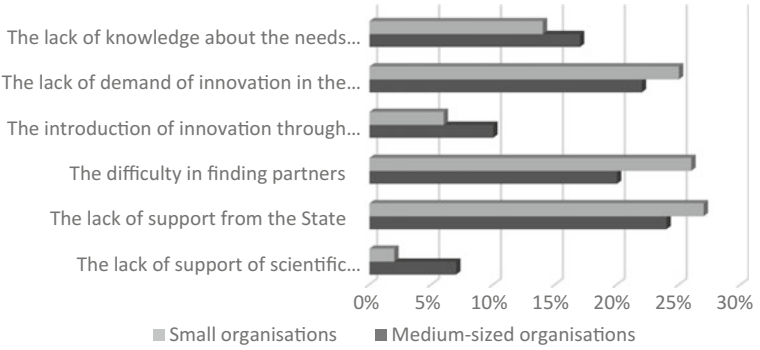

Fig. 4 External barriers to the implementation of open innovation (*source* own elaboration)

lack of support from the management, a low level of creativity among employees and their low qualifications, as well as no need for implementing innovations (1–2 % of responses). The results for medium enterprises basically reflect the responses provided by small organizations.

In case of external barriers, the main issues faced by small enterprises are a lack of support from the state and difficulties with finding the right partners for cooperation. Such enterprises are also concerned about a lack of demand for future innovations. They do not consider a lack of support from scientific institutions, including universities (2 % of responses) nor innovations introduced by their competitors (6 % of responses) a barrier. Medium enterprises also indicate a lack of support from the state in the scope of innovation as one of the main barrier for opening their processes to innovation. As before, the least important factor for such enterprises turned out to be support provided by scientific institutions.

5 Conclusions

Despite its growing popularity around the world, the concept of open innovation is still not widely known in Poland, thus only a small number of organizations applies the concept in its fullest extent. The majority of the research sample (around 55 %) are hybrid organizations, which use open innovations to a limited extent, equal to their use of internal innovation. Knowledge acquired outside the organization is often a substitute for the internal R&D activities.

By analyzing the responses regarding sources of innovation, it is clear to see that organizations from the SME sector more and more often search for innovation by using opportunities in their environment (12 % of responses), analyzing the needs of their clients (15 % of responses) and by browsing through the press, trade publications and patent databases (14 % of responses). The biggest incentive to use the open mod-el of innovation is mainly the need to optimize the ongoing activity of the enterprise (16 % of responses).

The research also indicates that the main internal barrier for organizations from the SME sector is the financial barrier (related to the costs of acquiring knowledge and its adoption within the organization—85 % of responses). Whereas one of the main external barriers, according to the respondents, is the lack of support from the state in the scope of innovation (27 % of responses). This raises concerns, especially when we consider the significant outlays (at the level of EUR 10 million for entrepreneurs, business support institutions, R&D institutions and public administration institutions, as part of the Innovative Economy Operational Programme 2007–2013) allocated to date to innovation-related activities in Poland. This may lead to a conclusion that Polish organizations are unable to find relevant information on programmes supporting innovation or are not interested in the subject at all.

A positive aspect of the research conducted is the conclusion that Polish organizations from the SME sector are interested in increasing the level of innovation, in particular, by using the knowledge, experiences and creativity of their employees (only 36 % of the organizations which participated in the study are closed investors). How-ever, not all organizations searching for external sources of innovation are supported by the management or a properly adjusted incentive system (which is usually adjusted to the closed model). Working with external organizations (establishing collaboration, maintaining relations, exchanging knowledge) is very challenging. At the same time, employees are awarded for the number of inventions made and implemented, rather than for collaborating with external entities. Additionally, the nature of cooperation with other organizations and its impact on the operation of the enterprise is rarely understood by the management.

The concept of open innovation in Poland is still new, however, the level of interest is growing continuously. Currently, implementation of innovation with the use of the open innovation model is supported by government initiatives (Horizon 2020 Pro-gramme), which will certainly lead to popularization of the concept among Polish organizations.

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Methods of Assessing the Level of the Technology Innovation and Polish Innovativeness in Years 2010–2014

Anna Maria Kamińska and Zofia Wilimowska

Abstract This paper is the review of methods that are used to assess the level of the technology innovation. Shown is the detailed scheme of technology transfer project and the most popular methods of the project management. This is followed by the innovation audit steps. Next section is an analysis of statistics of Polish innovation indexes. The contains the information about Global innovation Index and shown is Polish position among the all countries.

Keywords Technology innovation · Validation of technology · Innovation audit · Global innovation index

1 Validation of Technology Innovation

Technology innovation is an change of methodology of production or other process in the organization like enterprise. It is also a change in the way of the delivery of a product to a final customer. Technology innovation can be also an update of used software, equipment or in production itself. The aim of innovation (in) technology can be faster delivery of a product or delivery of new solutions. The result should be more effective production (volume of production) or more successful delivery [1].

The validation of technology innovation can be conducted in different approaches. Well known assessment of is financial analysis factors, that can describe the innovation level:

- Payback period;
- Net Present value;

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- Internal Rate of Return;
- Profitability index.

Factors mentioned above are the same as used in typical analysis of financial investments. It is difficult to use them to evaluate the technology investment, as the technology innovation project has many unknown areas.

This kind of analysis is based on planned economical values like the volume of investments, net income, cash flows of financial assets. The most important is to prepare realistic financial forecast (called financial pro-froma) for planned innovative project. The critical points, that needs to be considered are:

- Determination of analysis period. There is no algorithm, that would allow to determine the adequate period. It needs to be changed for every project individually, followed by product life cycle. For innovative projects it is usually 5–10 years.
- Preparation of the financial plan of the project, so there is a need to predict what capital expenditures, financing sources and financial statements are expected. This should be prepared based on anticipated investments, incomes and outcomes that will take a place after project implementation.
- Profit and Loss Account preparation, that is the result of comparing incomes and outcomes.
- Future cash flow, is the cash value that is necessary to operating activities.

All points mentioned above are hard to predict when talking about innovative project or process, this means, that the risk related with—is high. In general there are several areas of risk, that affects technology innovation like: Research & Development, Investments, Market, Business and many others.

It is common, that technology innovation is being transferred from other entities like universities or research and development (R&D) organizations to the company. As this process is very sensitive it is important to regularly evaluate and validate the process of innovation (technology) transfer. It means to measure the value and/or features of the technology transfer process. This evaluation consist of two features:

- Evaluation of technological strategy—to measure the effectiveness of implemented technology and assessment of the portfolio of the projects inside the company;
- Evaluation of project of technology transfer—assessment focused on one of implementation indicative.

Process of this kind of evaluation contains:

1. Preparation of the questions, that should be answered during the evaluation.
2. Determination of evaluation criteria.
3. Selection of the methods of work and evaluation tools.
4. Preparation of the evaluation agenda.

The results of the evaluation should be stored and presented with the regular reports. Each errors should be validated. Audit should answer several questions like:

is the process fulfilled according to initial assumptions and planned schedule? where there any derogations and what did cause it? is there a risk of not completing the process? does the effects are facing company needs? how to improve the process?

The detailed technology transfer project is shown on (Fig. 1).

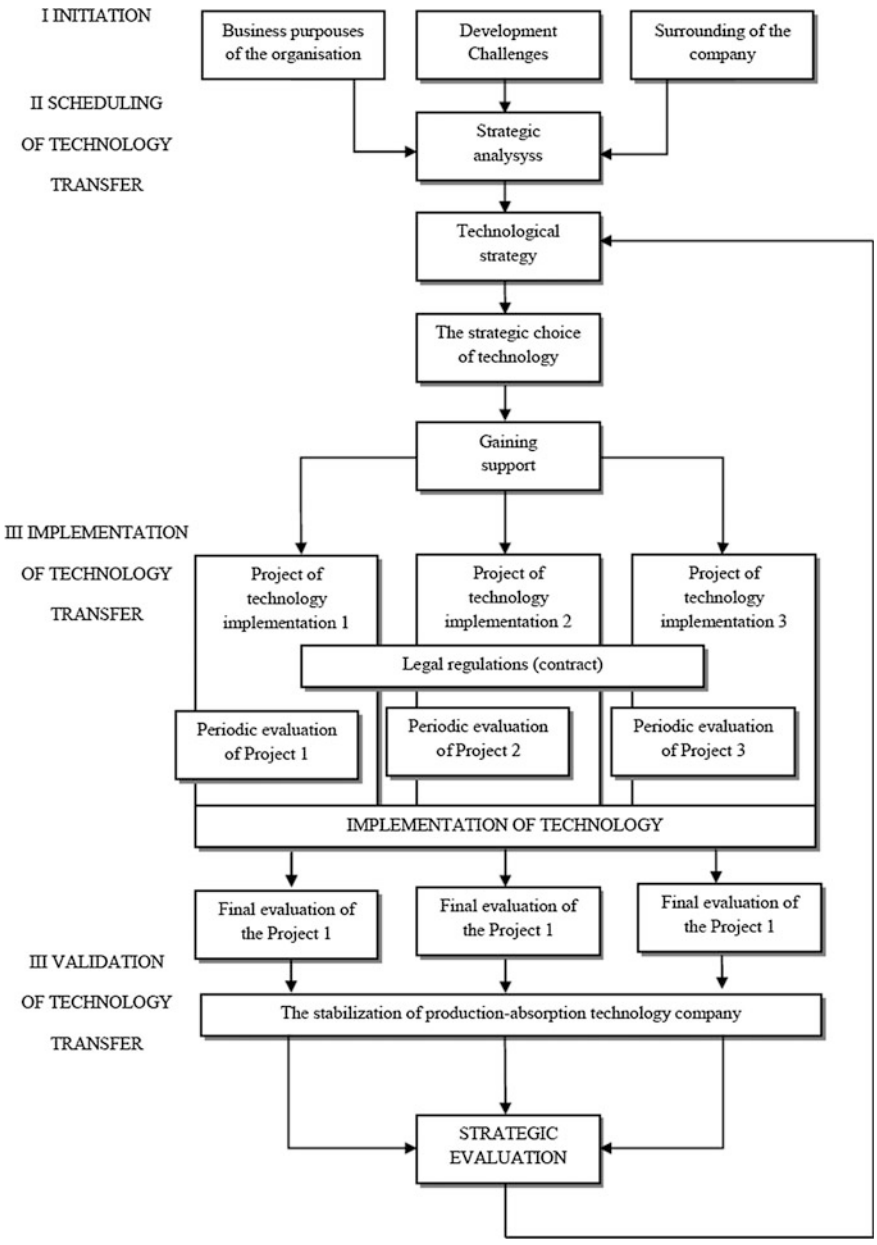

Fig. 1 Detailed scheme of technology transfer project and its validation [2]

Very important part of the realization of technology transfer process is to predict and avoid possible errors and eliminate them. That means that a part of project should be preparation of tools, that will help to avoid or limit the risk connected with inappropriate implementation of the risk [2].

Each technology innovation is implemented by the process, popularly named the project. It is very important to manage this project well. There are many project management methods, that depends on different factors as company environment, company habits or management attitude. On below there is a list of the most popular project management methods.

- PMBoK (Project Management Body of Knowledge), a standard proposed by Project Management Institute (the association for the project, program and portfolio management). PMI systematized standards and best practices into a Guide, where manager of the project can choose and follow the strategy [3].
- PRINCE2 (Projects In Controlled Environments) is a process-based method for effective project management. The main features of PRiNCE2 are: flexibility; business justification, Project structure preparation for for the project management team, planning approach based on products, dividing the project into two stages: manageable and controllable stages [4].
- SCRUM invented by Hirotaka Takeuchi and Ikujiro Nonaka is known as one of the Agile Project Management methods. This methodology consists that product development is divided into smaller, lasts up to one calendar month iterations called sprint followed one after another. It is commonly used in complicated projects, mainly in IT.
- XPM (Extreme Project Management) is the methodology of project management from the group of Agile Project Management methods. It is in use for high risk projects, mainly from IT field. The main accent is on human relations inside a project team and looking for effective solutions to avoid bureaucracy that I slowing the project.

It is up to the organization or project team if used method would be modified or if there will be created new method based on well known [2].

2 Innovation Audit

Innovation audit can be focused on two types of innovation: product innovation and innovation process. Both influence on the quality in organization. Product innovation is an innovation that should provide a product that will satisfy customer more effectively. Innovation process is a source of creating the value inside a chain: supplier—organization—recipient.

Innovation audit can be conducted according to chain of value creation and needs and requirements of customer. In practice used audit scheme looks as follows:

1. to designed innovative products.
2. Scheduling and implementation innovative production of products/services. Criteria is the level of utilization of innovative solutions to get the optimal production.
3. Sales. Audit criteria: the level of the implemented innovative sales method.
4. Maintenance. Audit criteria utilization of modification and development of the product and usage of new maintenance solutions. [5] Assessment of the requirement and needs identification (for the new product). Audit criteria are:
5. Knowledge about customer needs based on market analysis and market relations.
6. Utilization of tools of Quality Function Deployment. Analysis of connections between technical and functional parameters of produced products.
7. Targeted marketing directed to the group of the customers that needs innovative product. The criteria of the audit is the degree of implementation of the marketing strategy to applicable group of customers.
8. Legal confirmation of the agreement, that includes needs and requests of the customer in the area of the agreed level of innovation and its quality.
9. Design and development of new or modified product or service. The criteria are: utilization of innovative solutions on designed product/service; utilization of the quality tools used.

It is important to conduct the audit regularly, and use it to improve the process of the implementation of innovation inside the company.

3 Innovativeness of the Polish Economy in Years 2010–2014

There are many factors that affects the level of innovativeness of the economy, like human resources, financial resources, entrepreneurship, the ability to create relationships between companies, relations in R&D sector, IT structure and many others. It is a hard task when there is not any basic factor, that could measure it, so it is necessary to use a package of indexes.

Good example of successful analysis can be Summary Innovation Index for years 2004–2011 presented by European Commission (European Innovation Scoreboard and Innovation Union Scoreboard). The index is a arithmetic average of 24 partial indexes for 27 European Union countries and Croatia, Turkey Iceland, Norway Switzerland, USA and Japan.

Another example can be the report shown by Information Technology and Innovation Foundation that also uses a package of indexes directly or indirectly connected with innovations [6].

On below there is an analysis of Polish innovativeness based on data published by Polish Central Statistical Office.

First group of indexes is the share of innovative enterprises and innovative active enterprises. As it can be notice over 14 % of all companies are the companies, that

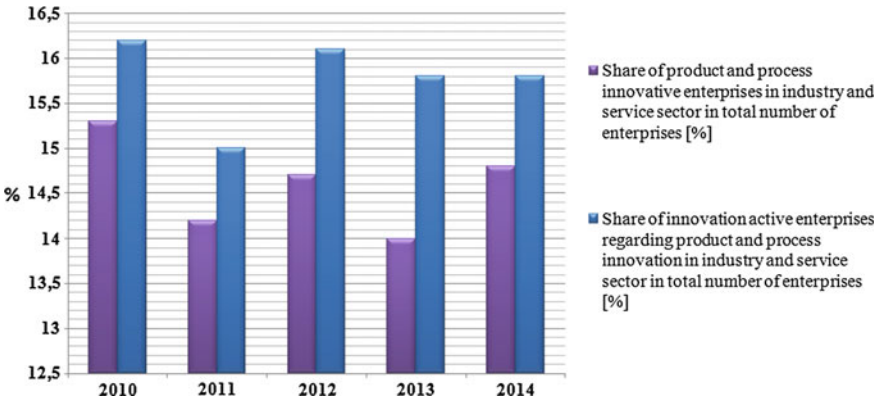

Fig. 2 The share of innovative enterprises and innovative enterprises active in Poland in years 2010–2014

are innovative. Over 15 % are innovatively active, that means that the enterprise did implement at least one innovation product or process or resulted in innovative activities discontinued or unfinished (Fig. 2).

There is an opinion, that Poland is a country with growing innovativeness. But when we would look at the three factors:

- organizational and marketing innovations in industry and service sector, in general it means the implementation of a new marketing concept or strategy that is different than enterprise's existing marketing methods (never used before).
- organizational innovations in industry and service sector (means new organizational method in enterprise's business practices).
- marketing innovations in industry and service sector.

The percentage of above innovations is decreasing what is visible on the (Fig. 3).

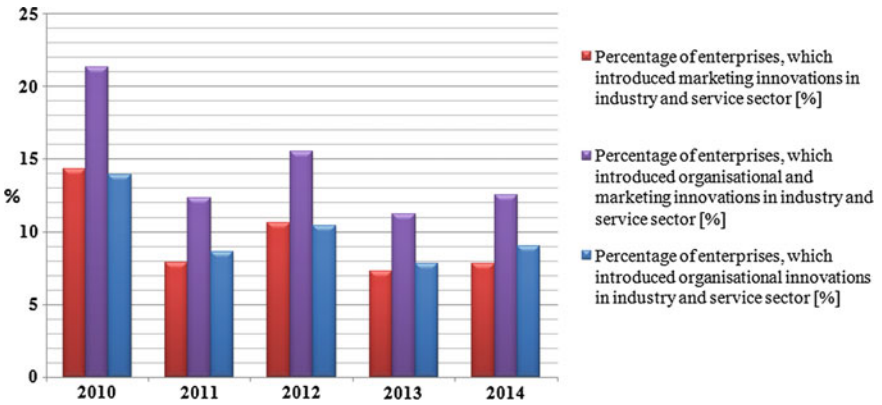

Fig. 3 Investment in innovation in Poland in years 2010–2014 [8]

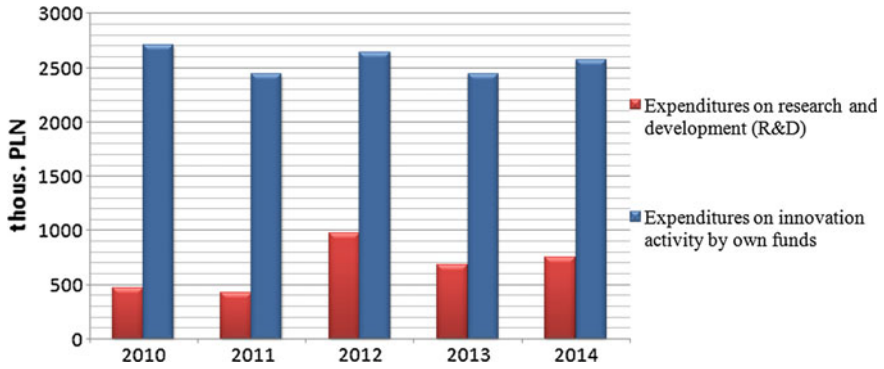

Fig. 4 Expenditures for innovation from own sources of Polish companies in years 2010–2014

Positive result gives the analysis of the expenditures on Research and Development. Since 2010 the volume of the expenses on this area is stable, about 2500 k PLN and does not changes rapidly what is a good trend.

The expenditures on innovation activity subsidized from own funds are growing, what can mean, that enterprises earn more and can spend more on innovation (Fig. 4).

Very important financing source of innovation are external sources. In Poland there are different types of founding. The most popular are funds received from: the state budget, the abroad (in non-repayable form), European Union or bank credits. As it can be noticed—the smallest support for innovations is from state budget. Mainly innovations are sponsored by abroad organization. This number is rising. It should be noticed, that those funds are non-repayable.

The tendency of financing the innovation from European Union is rising. This is related to the new UE Strategy that contains innovation support.

Also the founding innovation from bank credits is rising. It should be noted, that banks are very sensitive for risky projects, so the rise of this value can be the evidence that innovative projects in Poland are easier to validate than in the past, and that the trust in the innovative projects is also rising (Fig. 5).

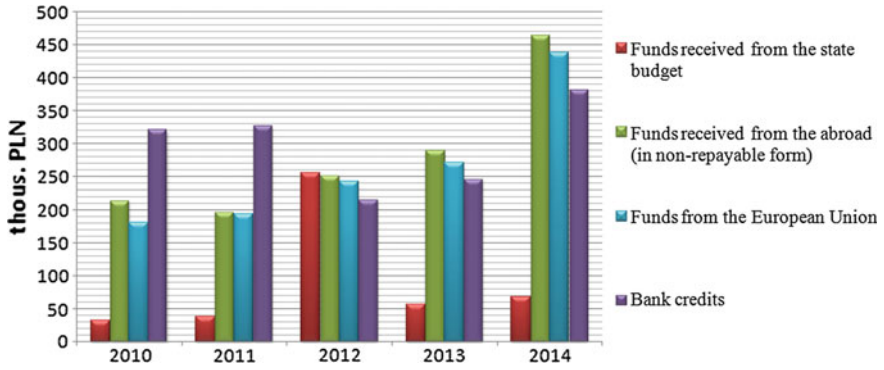

Fig. 5 Expenditures on innovation activity in Poland by the external source of funds in years 2010–2014 [9]

All indexes show on above can be rated positively, but this is only one perspective. It is necessary to compare polish innovativeness to other countries to make any opinion.

4 Poland from Global Innovation Index Point of View

Authors of this paper decided to use the Global Innovation Index (GII), that is used to build a ranking list of innovativeness over the world.

Since 2007 GII is published by two organizations: Cornell University, INSEAD, and the World Intellectual Property Organization (an agency of the United Nations).

The purpose of GII is to show the ranking of innovation capabilities and results over the world based on 79 ranked factors. The main areas that are scored are:

1. Institutions (among others: political stability, government effectiveness regulatory quality, ease of starting a business, ease of paying taxes);
2. Human capital and research (among others: Education: Expenditure on education, % GDP, Pupil-teacher ratio, Tertiary education: Graduates in science and engineering, Research & development (R&D): Gross expenditure on R&D, % GDP)
3. Infrastructure (among others: Information and communication technologies (ICTs) access and use, E-participation, General infrastructure, Gross capital formation, % GDP, Ecological sustainability: Environmental performance),
4. Market sophistication (among others: Ease of getting credit, Domestic credit to private sector, % GDP, Investment: Market capitalization, % GDP, Venture capital deals/tr PPP$ GDP; Trade and competition: Intensity of local competition)
5. Business sophistication (among others: Knowledge workers: Firms offering formal training, % firms; Females employed w/advanced degrees, % total; Innovation linkages: University/industry research collaboration, Patent families 3+ offices/bn PPP$ GDP; Knowledge absorption: High-tech imports less re-imports, % total trade; Comm., computer and info. services imp., % total trade)
6. Knowledge and technology outputs (among others; Knowledge creation: Domestic resident patent; Citable documents H index; Knowledge impact: New businesses/th pop, ISO 9001 quality certificates/bn, High- and medium-high-tech manufactures, Knowledge diffusion: High-tech exports less re-exports, % total trade)
7. Creative outputs (among others: Intangible assets: Domestic res trademark app./bn PPP$ GDP, ICTs and business model creation; Creative goods and services: Printing and publishing output manufactures, Creative goods exports, % total trade; Online creativity: Generic top-level domains, Video uploads on YouTube/pop.).

Top 10 innovative countries since four years (2012–2015) are Switzerland, United Kingdom, Sweden, Netherlands, USA, Finland, Singapore, Ireland Luxembourg and Denmark. The same countries are the leaders since 2012 but with different score.

Poland score is 40.2 points, that gives 46th place out of 141 [7].

It can be said, that Polish innovativeness is developing, but not as fast as in year 2010/2011. The position of Poland is relative to its expenditures to innovations.

Thanks to correct validation of the technology innovative projects and using proper methods of project management Poland can improve the value of innovations.

5 Conclusion

As the innovativeness is an area, that is hard to validate any prediction becomes unreliable. The solution is to assess the whole process, evaluate it and find out what are the risks connected with. There is a need to compare the results of different countries, so the worls organizations are preparing the indexes, that can show which countries are good innovators, so other can learn from them.

Poland is a country, that for many years wasn't developing. Now, for over a decade innovativeness is growing. Big help are founds fro European Union. When we look at the position in GII Ranking it can be said, that it is good, but when we would look at the position of other ci\unties in Europe—it's poor.

The assessment and evaluation of the innovativeness should be a good tool to find out what risks can be eliminated an how to develop.

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The Formation of Regional Strategy of Innovation-Industrial Development

Kozlov Aleksandr, Gutman Svetlana, Zaychenko Irina and Rytova Elena

Abstract An approach to formation of regional strategy of innovation industrial development is suggested in the research. The concept of system of regional indicators (SRI) is used for development of innovation-industrial strategy of regions of Far North of Russia. Set of regional strategic maps is presented in framework of this concept. This tool gives a possibility to define and organize subjects of innovation, objects of innovation, and helps to attract and redistribute resources for the innovation development. Regional indicators also allow the authorities to control the process of strategic goals achieving.

Keywords Innovation and industrial development · Strategy · Region · System of regional indicators · Far north

1 Introduction

Global economic trends analysis connects the country's level of industrial development and quality of life with the ability to adapt to changes resulting from the rapid scientific and technological progress. Results of scientific and technological development are determined by the effect and the cost of introducing new products and technologies, i.e. by the innovations efficiency. One of the main factors of economic growth and sustainable development of society today are scientific

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knowledge and technological inventions. According to various sources in developed countries of 70–80 % GDP growth is achieved by new technologies and inventions.

New economic category "innovation" was introduced at the beginning of the twentieth century by Austrian scientist Joseph Shumpeter. In his work "The Theory of Economic Development" (1911) Shumpeter [1] considered the question about new combinations of changes in the development and gave a full description of the innovation process.

Traditionally, innovation is referred the practical use of new idea from the technological development to the large-scale production and distribution as new products and services.

Up to the moment a law on innovations has not been passed in Russia. The existing legislation of 90s does not meet the requirements of the moment. Various factions of the Duma worked on a bill devoted to regulation of innovative activity in the Russian Federation, but in the end none of the legislation has been adopted. As a result, there is still no legal definition of innovation, innovation-active enterprises. In this paper, the definition of innovation will be used, according to one of the projects of the "Law on innovative activity in the Russian Federation". This definition seems to be the most complete and current. Innovation is a materialized result obtained by investing in new equipment or technology, in new forms of work organization of production, maintenance and management, including new forms of control, accounting, methods of planning, analysis, etc. (many organizational and technical, managerial, financial, commercial and administrative modifications).

For the industrial stage of economic development the main strategic factor of economic growth was, of course, production experience. The main distinguishing feature of the modern innovation stage of development becomes the scientific knowledge as a major factor of growth strategy. This transition entails structural changes in the global economy: the intellectual capital becomes the main type capital; modern production is characterized by an increased share of intangible assets; the constant search for new technologies becomes especially important, not only in production but also in management; thus, an innovative process becomes continuous. The main strategy for companies and for national economies becomes not only the import of investment, but also import of technologies and skills (human capital import).

Therefore, the development and implementation of innovations becomes a priority for the region's strategy, and affects all other areas of regional development including industrial development. The priority of innovation strategy meant, that innovation can help to implement the other strategic objectives to achieve not only economic but also social effect. One of the main goals of the strategy of innovation and industrial development can be the industrial development of the region as a whole and the individual businesses.

2 Existing Literature

Analysis of the literature showed that the regional strategies of innovation and industrial development are poorly developed problem. Scientific works can be divided into two large groups dedicated to: 1. industrial development and industrial management of the regions; 2. innovative development and innovation management regions.

The most extensive group of studies attracts the attention of authorities both federal and local level to the issues of regional industrial development: the purpose and objectives of the regional industrial policy are determined and priorities for its implementation at every level of government are formulated in these papers [2–9]. Some authors analyze not only general methodological provisions of the formation and implementation of industrial policy, but also factors affecting the level of socio-economic development of territories [10]. In the works [11, 12], the focus is concentrated on the territorial development of one region in terms of the level of industrial development. Unfortunately, proposed design is extremely specific and can be applied only in the concrete region. The selected work [13] shows an approach to assessing the level of industrial development of the region, based on the statistical information, as well as a number of key performance indicators.

The second group of researches includes works by both domestic and foreign scientists on the issue of innovation management. However, only a small part of them is devoted to the innovative development management of the region. [14–16] For example, in [17] presented a theoretical model of regional governance, aimed at effective use of region innovation potential. Similar ideas can be found in other research [18]. Authors suggested taking into account the specific features of regions in the construction of regional innovation development strategy presented in [19]. In terms of development of the Concept of regional indicators (CRI) are also interesting works [20–22]. In [20] authors pay attention to the importance of considering both external and internal factors that influence the innovative development of the region. But, they do not show cause-and-effect relationships between individual elements that contribute to the innovative development of regions.

Thus, there is a need to develop a new integrated approach to achieve the strategic objectives of industrial development in the region through the development of innovative economy, and improve the innovative activity of industrial enterprises in the framework of developed overall regional strategy.

3 Methodology

The methodological basis of the study was the balanced scorecard proposed by Kaplan and Norton [23], which served as the foundation for developing a system of regional indicators (SRI). SRI is an integrated approach that allows investigating

issues of development and implementation of regional strategy at different levels of regional authorities (region, municipality, enterprise).

4 Analysis

Innovation is a mechanism of influence on the process of regional development. The innovation performs the following three functions: reproduction, investments, stimulation. Innovations stimulate the industry reproduction of in the region, serve as a tool to attract investment and stimulate industrial development, as well as influence on the level of socio-economic development of the region indirectly.

At the same time, innovative activity of regional authorities can be defined as a process, the purpose of which is to stimulate the development of innovation in the region; to implement the scientific research and other scientific and technological achievements into new or improved products for the market, new or improved processes, and additional researches and development allowing to realize regional objectives. So, innovation management in the region can be described as a purposeful system of innovative activity management of industrial enterprises in the region and the relations arising in the process of moving innovations from the development stage to the commercialization stage to maximize the effectiveness of the innovation process as a factor of industrial and socio-economic development of the region.

If innovation-industrial management is regarded as a targeted system, it is possible to present it as a "black box". Between the input and output of the system there is an innovative process in the region, within which new ideas turning into modern new product (work, services) for further advancement in the market. Innovation management system has the ability to set goals, as well as any economic system. Its purpose is to define the basic parameters of scientific, technical and production activity of the industrial enterprises of the region in developing and implementing the latest products and technologies, further development of management and production in the area.

The objectives of the innovation management in the region are: the wording of the new goals of innovation and industrial development, the development of ways to achieve them, and the best selection of innovative ideas from the set of offered by enterprises. As for the company, the system of innovation management in the region should have an important property—adaptability and flexibility, i.e. the ability to quickly perceive innovation and change under the new situation.

The subjects of innovation management in the region are: investors, developers, industrial enterprises—users of innovative products, as well as authorities as the various infrastructure entities of supporting of innovation.

The objects of innovation management are innovation and the production process and economic relations between the subjects of the innovation market.

Innovation management system is a subsystem of regional management and at the same time independent system, with all its properties and attributes. Therefore, innovation management can be represented as the activities of regional authorities aimed at creating and ensuring the achievement of innovative goals of the regional economy through the rational use of human, material and financial resources, or the same kind of functional management, the object of which are the innovative processes in all sectors economy of the region.

However, there are some problems that do not allow the Russian economy to become innovative:

- The lack of experience in launching of innovation products in the market of the modern Russian research organizations. In the USSR, research organizations were mainly focused on the implementation of the state order, often military-industrial one.
- The absence of a legal framework of innovation activity. Despite the development of a number of projects, the law on innovations in the Russian Federation has not been adopted. In legal terms, the company leading innovation are now powerless, because there is no definition in the law of the concept of innovation and, consequently, there are no opportunities for continuous and systematic state supporting of innovation-active enterprises. Little attention is paid to the practical use of research results, funded from the budget. The share of budget expenditures in costs of small innovative companies is negligible.
- Low level of innovative activity of industrial enterprises in traditional industries. According to the survey of Center of the economic conjuncture of the Russian Government, the proportion of enterprises engaged in innovation is only 32 %;
- A limited set of benefits and preferences for innovation companies;
- "Brain drain". Today this phenomenon decreased in comparison with the 90-th years, but now this process has got other features: the young people leave of science and it is accompanied by the aging of the scientific staff. This is due to poor living conditions, low wages and lack of real significant assistance from the state in the form of grant support for research, as it is in most developed countries;
- Unfavorable business climate of the majority of Russian regions. In the ranking of the "Making business in different countries" Russia is constantly on the lower positions. The reasons for this are: the fiscal pressure, the lack of competition, the administrative barriers and weak support for innovative enterprises;
- Weak financial market. The lack of investment caused by numerous external factors (sanctions, legislation instability, etc.), as well as the internal factors of the Russian enterprises. According Pricewatehouse Coopers due to the opacity of Russian economy loses annually about $ 10 billion of foreign direct investment;

- Internal problems of Russian enterprises. Many Russian companies have obsolete fixed assets. Many unique technologies have been lost during the transition period of the Russian economy;
- A long payback period. This feature characterizes all innovative enterprises of all countries: according to the Harvard business review, 70 % of innovations end in failure or do not reach the planned result. But the high cost of capital in Russia and the lack of alternatives for financing innovation, lead to special acuteness of this problem in the Russian Federation;
- Poor innovation infrastructure. The innovative infrastructure of developed countries is formed on the basis of "bottom-up" approach, i.e. there are commercial organizations that take over responsibility for the promotion of new innovative companies. In Russia, such an infrastructure is not formed yet. According to the "top-down" approach Russian authorities are now trying to launch some elements of such an infrastructure, but, unfortunately, their efficiency is not as high as it is desirable.

Especially these problems occur in regions with economic-geographical specifics related to their position on the Far North. Analysis of the current level of industrial and the social development in most regions of the Far North has shown that the traditional approach to the development of the industries has not led to an growth of these areas. On the contrary, after the collapse of the USSR and the Russian economy transformation in these areas there is a substantial decline of industry and the social sphere. This situation requires a search for ways of reforming the economy of these regions on the basis of innovation. It can be argued that further industrial development of the Far North areas is only possible with the introduction of innovations. It is obvious that the region has a unique potential, in particular natural resources, but the extremely low temperatures, permafrost, low population density, associated with uncomfortable living conditions, weak infrastructure significantly increase the costs of construction and operation of industrial facilities. The way out of this situation could be the development of new industrial technologies aimed to realization of the powerful industrial potential of the region, taking into account regional specificity.

The analysis showed that many Russian regions have an industrial development strategy today, but only a few have also an innovative development strategy. It is clear that achieving the optimum structure of the subjects, objects and results of innovation is impossible without the unified strategy of innovative development of the region. This strategy allows linking the development, with the resources and performers, taking into account regional specificities. Therefore, in this research is suggested to use an integrated approach to the innovative activity management of the Far North territories, based on the development and implementation of system of regional indicators (SRI). The idea of an integrated approach to the strategic management of the territories of the Far North is based on the concept of balanced scorecard system, proposed by Kaplan and Norton [23, 24].

Studies of industrial innovative development in the Far North areas allows to conclude that there is a relationship between the level of indicators of innovation and industrial development of the region and the availability and implementation of innovative development strategies.

To verify this thesis, a cluster analysis was performed, which revealed clusters with different levels of innovation and industrial development (low to high). For example, the Nenets Autonomous Okrug, Chukotka, Magadan region were in a cluster with low levels of innovation and industrial development. This Murmansk Oblast, the Republic of Sakha (Yakutia), the Khanty-Mansi Autonomous Area—with a high level of development, YaNAO—the level of development above the average. This can be justified by the successful implementation of innovation development strategy in part of these regions. Thus, we can assume that the level of development of the region depends on the existence and implementation of special innovation strategy.

5 Findings and Proposals

In this research is presented an approach to the regional innovation management on the basis of the SRI for development of the territories of the Far North. Strategic maps, aimed at increasing the level of innovation development in the region were

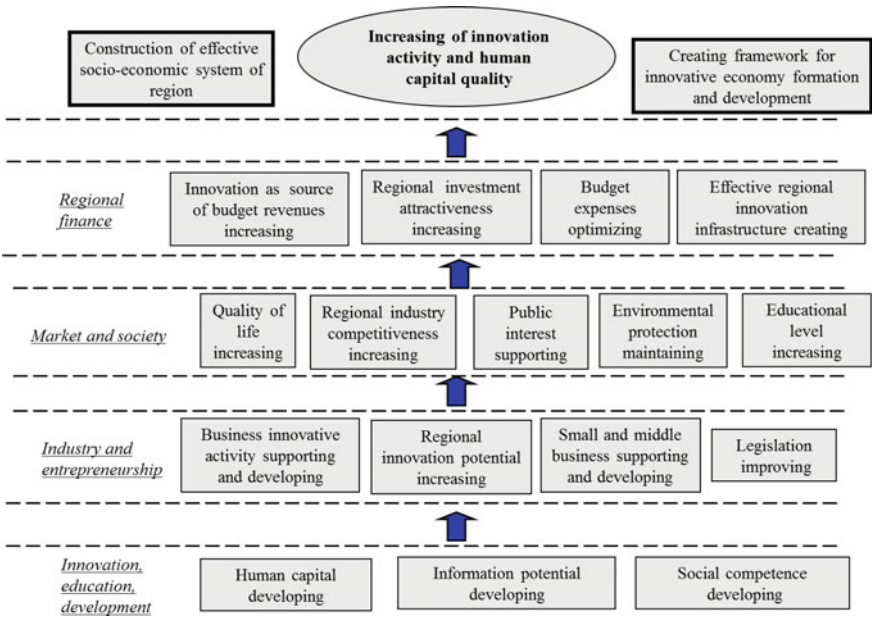

Fig. 1 General strategic map

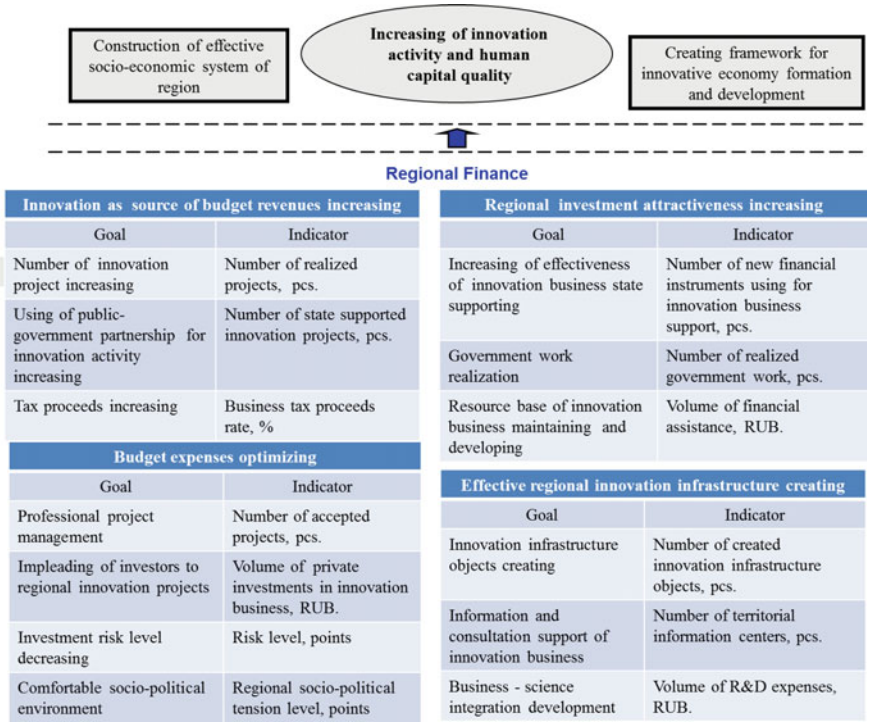

Fig. 2 Component "Regional finance" strategic map

drawn up. According to the idea of R. Kaplan and D. Norton, general strategic map and strategic maps for four main components, each of which reflects the specific targets for increasing innovative development in the region, were compiled (Figs. 1,2,3,4 and 5).

General strategic map (Fig. 1) reflects the entire concept of creating the SRI, and it indicates the direction of regional innovative management through consistent implementation of measures improving of regional innovation activity, from the creation of the intangible assets and human capital, to improving the industry structure in the base of innovation that have a direct impact both on the regional markets and on the quality of life. Only consistent implementing all the measures indicated can give positive cash flow from the innovation-industrial regional management. To clarify this main map up to strategic targeted interventions were built strategy maps for each of the components (Figs. 1,2,3,4 and 5).

However, an analysis of the main indicators of industrial and innovative development of the territories of the Far North shows that these areas have very

Educational level increasing	
Goal	Indicator
New educational programs developing	Number of new educational programs, pcs.
Increasing the number of people with higher education	Number of people with higher education, people
Innovation-active citizens increasing	Number of seminars and consultation, pcs.
Creating of innovation experience centers	Number of centers, pcs.

Regional industry competitiveness increasing	
Goal	Indicator
Innovation products import decreasing	The volume R&D imports, Rub.
Innovation diffusion increasing	The number of sent / received technologies, pcs.
Innovation goods and services production and sales increasing	The share of innovation regional product in the total regional product, %

Environmental protection	
Goal	Indicator
The neutralization of the negative effects	CO2 level decreasing, %
Level of environmental protection increasing	Number of received environmental certificates, pcs.
Increasing of companies energy efficiency	Energy efficiency indicators of the company, W/Rub.

Public interests supporting	
Goal	Indicator
Economic security level increasing	The share of food imports in total imports, %
Raising the level of legal protection of innovations	Number of patents / licenses, pcs.
Increasing the volume of realization of innovations	Number of commercialized research confirmed patents, pcs.

Quality of life increasing	
Goal	Indicator
Unemployment level decreasing	Number of new working places, pcs.
Increasing the number of people with above average income	The share of entrepreneurs satisfied by financial situation,%
Raising the average level of income in the region	Average wage in the region, Rub.

Fig. 3 Component "Market and society" strategic map

different level of innovation development. The clustering analysis was carried to differentiate areas of the Far North into groups. Therefore, to further strategic management of the innovation-industrial development of areas of the Far North is necessary to develop more detailed strategic SRI-maps, which take into account the actual level of development and innovation in the areas, and a number of specific factors that are shaped by their economic and geopolitical position.

6 Conclusions and Further Research

Due to increased competition on the world market and increasing the share of high-tech products in all sectors of the economy, particular importance for any state acquires its innovative potential. The most important tasks of the government

Business innovative activity maintaining and developing	
Goal	Indicator
Increasing the number of innovative enterprises	The share of innovation active enterprises in the total number of enterprises in the region,%
The creation of new types of innovation active enterprises	The number of new innovation enterprises, pcs.
Start-up creation	The amount of grants for the creation of new innovative enterprises, million Rub.

SME supporting	
Goal	Indicator
Number of SME increasing	Number of SME companies, pcs.
Involvement of indigenous peoples in the SME	Number of SMEs indigenous peoples, pcs.
Improving the competitiveness of SMEs in the region	The volume of support for SMEs, million Rub.
Raising awareness of entrepreneurs	Number of consulting activities for SME , pcs.

Regional innovation potential developing	
Goal	Indicator
The increase in R & D due to commercial financing	Business Expenditure on R&D, million Rub.
The development of financing institutions	The number of venture capital investments in the region in total venture capital investment in the country, %
Attracting scientists to the implementation of innovative projects	The number of doctors of sciences, working in the business, people.

Legislation improving	
Goal	Indicator
Clustering of enterprises engaged in innovative activities	Number of clusters, pcs..
Formation of the legal framework of cooperation in innovations	The number of signed partnership agreements in the sphere of innovation, pcs.

Fig. 4 Component "Industry and entrepreneurship" strategic map

management can be considered stable and rapid growth of innovation in all sectors of the economy. The government should initiate the process of innovation in the region as a participant and organizer. One approach to solving the problem of increasing the level of innovation and industrial development in the region would be to develop strategic maps SRI aimed at improving regional innovation development in the territories of the Far North. This approach allows us to visualize an regional innovative management, to see the so-called "weak and narrow" places of a number of areas, to provide financial resources and monitor the achievement of targets as for the executors of the projects, also for government.

Human capital developing		Information potential developing		Social competence developing	
Goal	Indicator	Goal	Indicator	Goal	Indicator
Formation of high education system based on regional special features	Number of new student places in universities, pcs.	Regional scientific publication activity increasing	Number of scientific publications in the region, pcs.	Integration of indigenous peoples in the regional innovation processes	The number of indigenous people employed in innovation-active enterprises, people.
Formation of the regional scientific potential	Number of graduate students, people	Regional information activity improving	Number of placed information materials (website, media), pcs.	Using of key competencies of indigenous people on regional innovative enterprises	The share of innovative products of indigenous peoples in the region's GRP,%
Smart-working advantages using	Number of enterprises with a flexible schedule for employees, %	Regional analytical activities developing	Number of strategic and statistical research, pcs.		

Fig. 5 Component "Innovation, education and development" strategic map

Although the business is definitely ahead of the authorities in the initiative and efficiency, but the embodiment of private strategic plans is often hampered by lack of infrastructure. Solution of infrastructural problems is one of the main functions of the state in the modern economy, and especially in the innovation sphere.

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Modular Experience-Based Smart Innovation Engineering System

Mohammad Maqbool Waris, Cesar Sanin and Edward Szczerbicki

Abstract The current paper presents the systematic approach for supporting the product innovation process of manufactured products. The proposed system uses a collective, team-like knowledge developed by innovation related experiences of the formal decisional events. The proposed system for smart innovation engineering carries the promise to support the innovation processes in a quick and efficient way. It stores the past decisional events or sets of experiences related to innovation issues, which significantly enhances innovation progression. Implementing this system in the process of product innovation enables entrepreneurs and organizations to take enhanced innovative decisions at appropriate time.

Keywords Smart innovation engineering · Product innovation · Product design · Set of experience · Decisional DNA · Smart knowledge management system

1 Introduction

Product innovation process is highly cumbersome as it requires a wide range of knowledge of all the similar products, their past decisional history while some changes were made, the effect of those changes on product from various perspectives and, knowledge about the new technological advancements or new materials that have the potential to be incorporated in product. For the survival and prosperity of the manufacturing unit, entrepreneurs need to find out new ideas that can be implemented in the products leading to innovation. The reasons are frequent

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changes in the lifestyle of the users, rising costs of materials and energy, competition in the market at national and international level, and emerging technologies, among others. The current study employs a systematic approach for product innovation.

Both knowledge and experience are essential attributes of an innovator. They are necessary to find the optimal solution for the changes required to achieve innovation. These changes are based on the innovative objectives reapplied to the established, existing product. Innovators not only need to take proper decisions, they have to do this quickly and systematically so that the changes in the product may be implemented at the required time. We try to address this problem by proposing a system that uses a collective, team-like knowledge developed by innovation related experiences of the past.

In this approach past experiences based on innovation decisions are stored in a Smart Knowledge Management System (SKMS) [1] and recalled during the innovation problem solving process. Such SKMS provides quick optimal solutions to a particular innovative challenge. This Smart Innovation Engineering (SIE) System carries the promise to support the innovation processes in a quick and efficient way. It stores the past decisional events or sets of experience related to innovation issues, which significantly enhances innovation progression. Implementing this system in the process of product innovation enables entrepreneurs and organizations to take enhanced innovative decisions at appropriate time. The system grows and matures with time gaining increasingly more expertise in its domain as it stores information, knowledge, and data related to the past formal decision events.

2 Background

2.1 Product Innovation

Innovation can be described as making changes to something established by introducing something new. It can be broadly divided into three types: Product innovation, Process innovation and Service innovation. Product innovation is applied in making changes to tangible products, it can be incremental or modular. Process innovation is applied by making changes to processes, like replacing some manufacturing process with another one that is cheaper or increases its quality. Service innovation on the other hand is applied in making changes to services like baggage handling system at the airport. The present research deals with the product/process innovation of the manufacturing products in general. There are three types of possible approaches in solving innovative problem [2]: a flash of genius, empiric approach, and methodical approach. Out of these the methodical path is a systematic approach to solve the innovative problem. The current study employs the systematic approach to support the product innovation problem termed as Smart Innovation Engineering [3–5].

Innovation is defined as the process of making changes to something established by introducing some-thing new that add value to users and contributes to the knowledge store of the organization [6]. Frishammar [7] points out that a strong emphasis on user information leads to incremental rather than radical product innovation. Incremental innovation also involves lower risks, since user needs are easier to forecast over a shorter time span, and the product development process is less complex. It may also provide financial advantage, since the relative investment is low and revenue and profits show up faster [8].

However, radical innovation calls for a leap of faith as it depends on new assumptions about user value and the company's ability to satisfy that value. The outcome is highly unpredictable and involves higher risk of failure [9]. The value of radical innovation is not always measurable solely in terms of commercial success. There are certainly cases where a radical product innovation has brought strong communicative value for the firm despite a lack of commercial success [10].

2.2 Set of Experience Knowledge Structure and Decisional DNA

The Set of Experience Knowledge Structure (SOEKS or simply SOE) comprising Decisional DNA (DDNA) is a smart knowledge structure capable of storing explicitly formal decision events [1, 11, 12]. This smart knowledge based decision support tool stores and maintains experiential knowledge and uses such experiences in decision-making when a query is presented. The SOE has four basic components: variables (V), functions (F), constraints (C) and rules (R) [13] and it comprises a series of mathematical concepts (logical element), together with a set of rules (ruled based element), and it is built upon a specific event of decision-making (frame element). Its structure is motivated by Artificial Bio-inspired intelligent techniques supporting knowledge-based solutions of real world problems and has enormous potential to enhance automation of decision making and problem solving for a number of diverse areas, creating unprecedented research opportunities in an extent of fields. Applications of SOE and DDNA have been successfully applied in various fields like industrial maintenance, semantic enhancement of virtual engineering applications, state-of-the-art digital control system of the geothermal and renewable energy, storing information and making periodic decisions in banking activities and supervision, e-decisional community, virtual organisation, interactive TV, and decision support medical systems for Alzheimer's diagnosis to name a few. For details see Shafiq et al. [14]. Our research converges on the application of SOE in the development of systematic product innovation.

A formal decision event is represented by a unique set of variables, functions, constraints and rules within the SOE. Groups of SOE are called chromosomes that represent a specific area within the organization and store decisional strategies for a category. Properly organized and grouped sets of chromosome of the organization is collectively known as the Decisional DNA of the organization.

3 Smart Innovation Engineering (SIE)

Before starting the innovation process, the initial innovative objectives must be stated clearly. These initial innovative objectives can be found by various techniques for obtaining user input, such as lead user analysis [15], beta testing [16], consumer idealized design [17], use of online user toolkits [18] to name a few. Apart from that the initial innovative objectives can be obtained from experts' advice or new technological advancements. These objectives are in the form of functions or features of the product that are technically attributed to some sub-assemblies or components of the product.

A methodology for the systematic placements of functionality-based components into a hierarchical ontology was proposed by Bryant et al. [19]. A list of more than 100 distinct generic component terms is provided in Kurtoglu et al. [20]. Centered on this functionality-based hierarchy, one can proceed to select the appropriate product needed for a particular analysis. The extended functional hierarchy shown in Fig. 3 is used to arrive at the position of a Screw Jack which is a product selected for initial case study illustrating this approach. This product is considered to be further

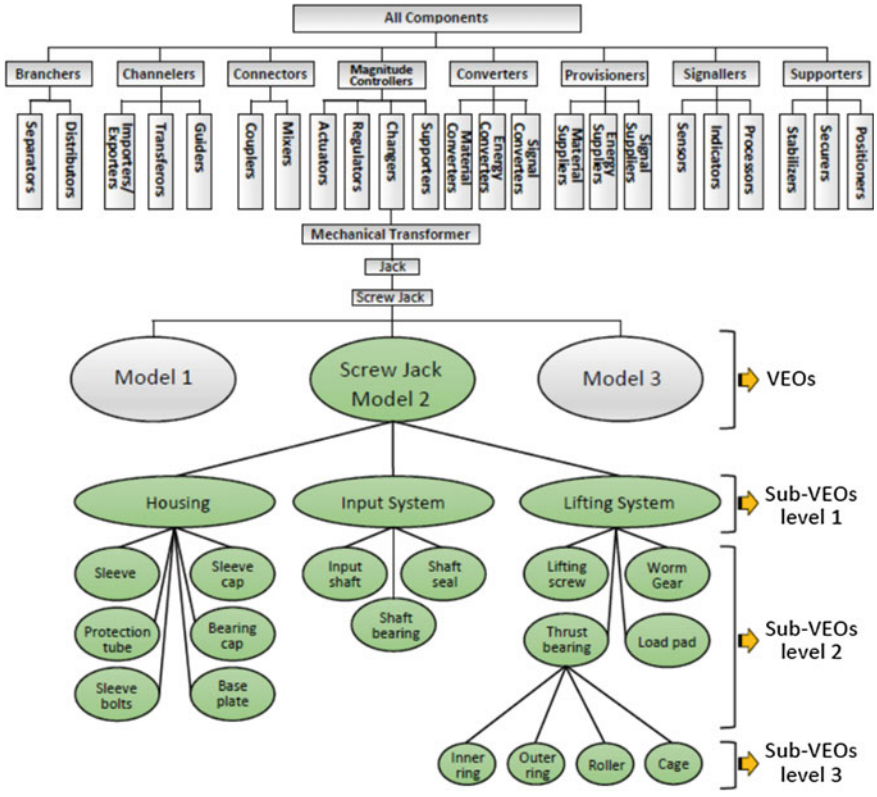


Fig. 1 Function-based hierarchical structure and representation of a Screw Jack

represented as a Virtual Engineering Object (VEO) [21, 22]. The concept of VEO captures the combined virtual/real world exemplification of an engineering artefact.

As shown in Fig. 3, first the product under consideration is structured in terms of the hierarchy of nested parts. Then, its VEO representation (in this case the Screw Jack Model 2) is divided into a number of subsystems performing specific VEO functions, which in Fig. 1 are denoted as sub-VEOs level 1. Similarly, sub-VEOs level 1 is decomposed into lower level subsystems shown in Fig. 3 as sub-VEOs level 2, which are subassemblies associated with some sub-functions that collectively perform the function at sub-VEO level 1. This nesting continues until the subsystem level reaches the basic element level that cannot be decomposed any further.

3.1 Architecture of SIE-DNA

The conceptual architecture of SIE-DNA is shown in Fig. 2. It is the unique SOE based experience representation structure capable of capturing, storing, adding, improving, sharing as well as reusing knowledge in innovation related processes and decision making in a way similar to an innovator or entrepreneur. It contains knowledge and experience related to each important feature of a product. This information is stored in eight basic modules of a SIE-DNA (Fig. 2): Characteristics, Functionality, Requirements, Connections, Process, Systems, Usability, and Cost.

The five modules (Characteristics, Functionality, Connections, Requirements and Process) can be extracted from the VEO/VEP-DNA developed by Shafiq et al. [21, 22]. These five modules are used by this system to capture the knowledge related to the manufacturing of the VEOs.

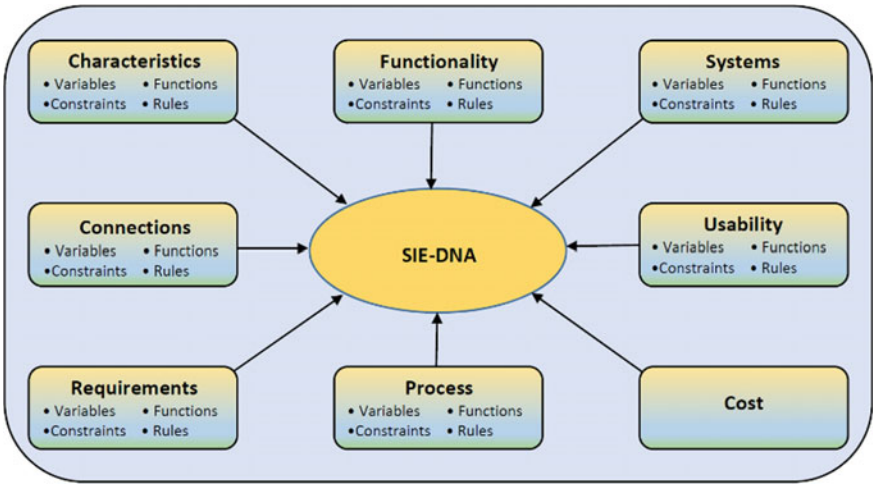


Fig. 2 Architecture of SIE-DNA

Three additional modules depicted in Fig. 2 as Systems, Usability and Cost. The Systems and Usability modules are the main modules crucial for the working of SIE system that can be realized by the type of knowledge they contain as described below.

Systems represent the knowledge about the relationships between various sub-VEOs like their hierarchy and dependability so as to embody a complete product structure and its logic. It also stores the past history of VEOs that were used for achieving identical functionalities as well as the possible alternative VEOs that have the potential of replacing the current one. This module is continuously updated with the alternative VEOs used in similar and advanced new products and new technological practices, new inventions, and new advanced materials. This module is crucial for innovation process.

Usability represents the knowledge about the use of a particular sub-VEO of the given product in other products. This helps in assessing its performance in other domains from the perspective of possible application elsewhere. It contains information on which products have stopped using the given sub-VEO, in which products it has been introduced recently, and its effect on the performance, popularity, sales or price of the product.

Cost represents the knowledge about the total cost of each sub-VEO of the product, the assembly cost of a group of sub-VEOs, and any other cost associated with the product manufacture, usage, maintenance etc.

3.2 Working Algorithm of SIE

The algorithm for the working of SIE system is shown in Fig. 3.

The working of the SIE system can be divided into five main steps (Fig. 3) that are described below:

Step1 Input Query (Initial Innovative Objectives): The query based on initial innovative objectives is fed into the SIE-DNA system. For the present case study, let us consider the initial innovative objectives to be

a. More Stability, b. Low maintenance
c. Portability, and d. Ease of Operation

Step2 Build SOE from Query: This query is converted to a SOE containing information in the form of a unique combination of variables, functions, constraints and rules.

Step3 Compare SOE Query with previous SOE: The present query is then compared with the previous SOE stored in the SIE-DNA. A typical structure of the information inside the SOE is shown in Fig. 4. It contains basically the list of initial innovative objectives, final innovative objectives (objectives selected by the system out of the initial innovative objectives to make changes into the product), list of changes in the product based on the

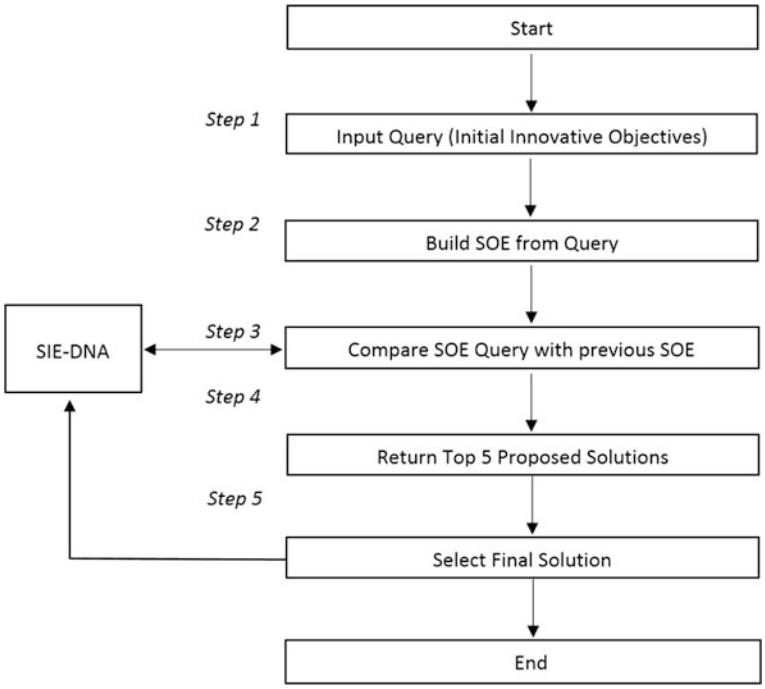
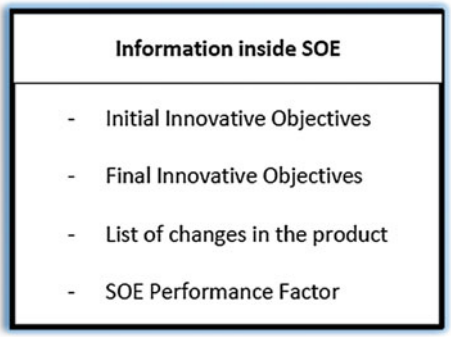


Fig. 3 Algorithm of SIE system

Fig. 4 Typical information outline inside the SOE



final innovative objectives and priorities and, SOE performance factor that is a measure of the effect of that innovation on the product.

At this stage, the query is compared with the previous SOE on the basis of Initial innovative objectives. Consider the Table 1, the SOE are ranked according to the higher SOE Performance Factor (SPF) and number of common Initial Innovative Objectives.

Table 1 Initial and final innovative objectives of previous SOE in the SIE-DNA

	Initial innovative objectives	Final innovative objectives
SOE 1 (SPF)	–Self locking –Ease of operation –Prevent overextending –Portability	–Ease of operation –Self locking
SOE 2 (SPF)	–Prevent overheating –Bending of handle –Ease of operation –Portability	–Ease of operation –Portability
… … …	… … …	… … …
SOE n (SPF)	–More stability –Low maintenance –Less corrosion	–More stability

Step4 Proposed Solutions (say top five): Based on the ranking of the SOE in *Step 3*, the system then evaluates the Final Innovative Objectives (Table 1) of the ranked SOE. After calculations, the system presents the Final Innovative Objectives of the present query as shown in Table 2. The final objectives of the present query are then further divided down into finer objectives. The final objective 'ease of operation' is further divided into finer objectives (Table 2). It is a logical and technical link between the final objective and the parts/components through which this objective can be altered.

Table 2 Innovative objectives' breakdown of the present query and its connection with parts/components of product

Initial innovative objectives	Final innovative objectives	Technical breakdown of objectives	Connection with parts/components
More stability	More stability		
Low maintenance			
Portability			
Ease of operation	Ease of operation	Smooth movement	
		Easy handling	
		Fatigue of user	
		Ambient conditions	
		Less friction	Friction between screw and nut
			Type of lubrication
			Friction between input shaft and worm gear
			Friction in thrust bearing

For example 'ease of operation' can be divided into finer objectives viz: easy handling, smooth movement, less friction, fatigue of users and, ambient conditions. Further finer objective 'less friction' can be controlled by controlling various parts/components of the product as listed in Table 2, i.e. friction between screw and nut, type of lubrication, friction between input shaft and worm gear and friction in thrust bearing. These parts/components also have weightage for the objective 'friction' indicating the percentage of the total friction that depends upon this part/component. Similarly all the Final Objectives are divided down and linked to the parts/components to be changed having respective weightages.

These parts/components (VEOs) will be replaced by the alternative VEOS present in the *System* module (Fig. 2). Every alternative VEO will be analyzed by collecting the information from the *Usability* module (Fig. 2) about its performance in other similar products for that particular objective attribute. There can be one or more objectives attributed to a particular VEO and also having different weightages respectively (for example input shaft can have attributes like friction, maximum load, corrosion index etc. with their respective weightages). Once this analysis is done for all the final objectives, the system then present the set number of results in the form of list of alternative VEOs that have the potential of replacing the current ones for facilitating the innovation process.

Step5 Select Final Solution: Based on the priorities set by the user, final solution is selected for facilitating the innovation process based on the query presented. Once the final solution is selected, it is sent to the SIE-DNA and stored there as a SOE that can be used if a similar query is presented in future. In this way the system gains experience every time a query is presented thus gaining more and more expertise in its domain.

4 Conclusion

This research introduces the concept of Smart Innovation Engineering that support product innovation problems solving. The presented concept is based on knowledge representation structure that applies past experiential familiarities and carries the promise to support the innovation processes in a quick and efficient way. The proposed decision support system is dynamic in nature as it updates itself every time a new decision is taken. The concept is illustrated with the example of a Screw Jack studied as the case that helps to understand the architecture and the working of the proposed system. In the next step the components of the introduced architecture will be refined in detailed algorithm and translated into software representation on a Java platform.

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Part III
Finance Management

The Acquirement and Functioning of Mezzanine Capital on the Example of Enterprises Operating in the Republic of Poland

Zbigniew Kuryłek

Abstract A survey of international literature provides an overview of mezzanine capital and its comparison with other sources of funding. It also explains the characteristics of the cost of financing, taking into account various forms of compensation for the investor. The aim of this study is to analyze the conduct of companies in the initial period after obtaining mezzanine capital, while functioning in general conditions of economic growth. Tools used for the analysis of hypotheses were statistical methods applied for the selected economical and financial figures. The performed analysis of mezzanine financing was also used for the evaluation of size of enterprises applying this method of financing. Studies have shown the correlation of net sales revenue and net profit. The analysis also proved that it is mostly medium and large enterprises from developing countries, who receive funds in form of mezzanine capital. While applying for this type of funding the companies have had stable cash flows, but their access to the required amount of capital was limited.

Keywords Mergers and acquisitions · Leveraged buyouts · Mezzanine capital

1 Introduction

Seeking methods of financing businesses involves a selection from a wide spectrum of possibilities. There are many alternatives, but they must be adequately and properly matched to the requirements and possibilities of a given company. Increasing globalization and improving quality of technical infrastructure contributed to the development of financial engineering. The current conditions allow for examining a range of instruments in the process of searching for methods of financial support for companies. Relatively low interest rates around the world and significant variability on financial markets and foreign exchange markets allow for a

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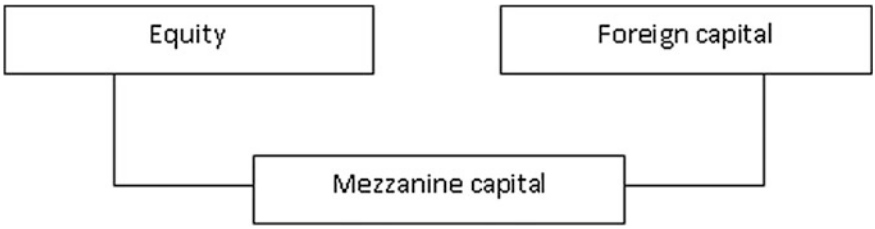

Fig. 1 Share of mezzanine in the capital structure (*Source* Own elaboration.)

wide selection of instruments and relatively low cost of financing. Thus, financing methods may be selected and adapted to current needs or new investment plans of companies. Thus, criteria for granting funding by financial institutions and the availability of funding sources are becoming key.

The wide spectrum of possibilities, together with the criteria for granting funding may result in a considerable limitation of the range of financing options. In the current situation of dynamic changes in business environment and the ambitious expansion plans for companies, availability of funds is crucial for achieving business objectives. For these reasons, the companies seek out prospects for their dynamic development. Insufficient fixed assets of companies with a potential for development may reduce their possibilities of obtaining funds. This may constitute a barrier for further growth of the company and its market share. Methods of hybrid funding, especially mezzanine capital, can facilitate exploitation of the current potential of business entities. This type of funding involves a combination of equity and debt (Fig. 1).

2 Description of Mezzanine Capital

From the viewpoint of the company's capital structure, mezzanine can serve as its complementary capital (Fig. 2), or as a major funding for financing transactions. It constitutes an auxiliary capital for the conglomerate of funding, but especially, it provides funding to companies without "strong" collaterals that would allow obtaining an alternative type of financing. The cost of capital is higher than a bank loan, but it gives the possibility of obtaining funds when other sources are unavailable (Fig. 2).

The function of mezzanine capital is financing the leveraged buyout of another company. Mechanism of this instrument (Fig. 3) can be adjusted to the current financial conditions of the company. The repayment program adjusts the amount of the interest paid to the later cash flows. The remaining value of interest is accumulated at maturity as a repayment of the remaining interest and capital. The remaining interest is shown in accounts, but have no impact on current business operations. A flexible approach improves the use of the company's potential,

Funding source	Proportion of funding in the structure of company's capital [%]	Expected rate of return [%]
Bank loan	30% - 60%	5% - 12%
Mezzanine capital	20% - 30%	13% - 25%
quity	20% - 30%	25%+

Fig. 2 The share and the expected rate of return from individual sources of capital (*Source* Silbernagel C., D. Vaitkunas D., Mezzanine finance, Bond Capital, p. 1–7 [12])

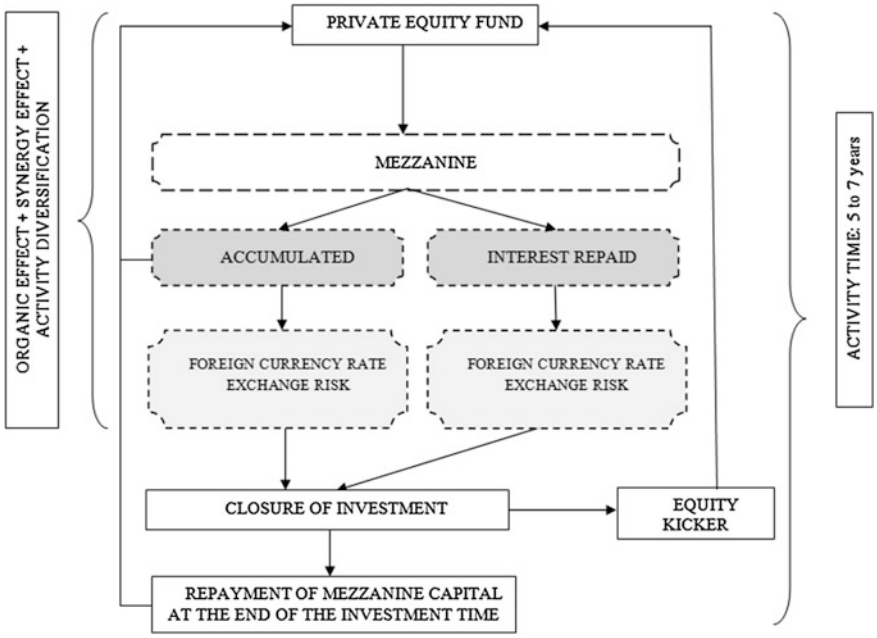

Fig. 3 Concept diagram of mezzanine financing model. Payment of interest in foreign currency is divided between the investor and the capital covering the outstanding balance that is paid at the end of funding period (*Source* Own elaboration.)

whereas the repayment of capital and interest is made after the end of transaction. This is the time when the company generates higher cash flows and its business operations are more dynamic and bring higher net profit.

3 Research Hypotheses and Survey of Publications

International literature on the subject of mezzanine financing is relatively scarce. In recent years, the number of studies related to this issue has been increasing, which does not change the fact that the available material on the mezzanine remains limited.

3.1 Publications on Mezzanine Capital and Capital Structure

When focusing on methods of raising funds and considering the structure of capital in a company, it should be noted that it was determined over the years that these matters are of great importance for the functioning of business entities. The MM theory [1] takes into account and emphasizes efforts for the efficient use of debt and equity ratio. Opportunities and threats arising from the use of debt were defined, as well as the fact that the value of a company does not depend on its capital structure. In later years, researches have shown the influence of tax shield on tax optimization and benefits arising from the use of debt [2]. Debt can cause beneficial results due to the strategy of financial flows management. It eliminates the company's financial surpluses, enforcing a more sound financial management [3]. Efficient use of capital structure depends on the financing method, the choice of which should be made according to the following pattern [4]: use the company's internal capital first, then the external capital and finally, the equity. This order may prove to be of vital importance especially for small and medium-sized companies with limited access to financial markets or small chances for obtaining funding [5]. This results in an equity gap, which can pose a barrier for further development. It is difficult, or even impossible, to identify a single solution that would be best for optimization of the capital structure, which is why the companies often choose the combination of several different funding sources, depending on circumstances [6], taking into account all or part of mezzanine capital. Obtaining funding opportunity is a crucial issue; but, even so, the existing or expected level of debt should be carefully considered. The increase in debt facilitates development and making investments only to a certain level. If it goes beyond a critical point, the company encounters drawbacks affecting its value [7].

Mezzanine financing is flexible and tailored to the needs a company, but the company should have stable cash flows and experienced management staff for

securing the proper distribution of mezzanine capital [8]. This type of funding is an important alternative in situations when economic environment suffers deterioration, especially during a crisis, when the availability of other financing sources is limited [9]. The conclusion is that mezzanine enables the realization of investment without losing the ownership control at a time when the company lacks a sufficient volume of financial resources [10]. Hybrid capital can be extracted from mezzanine capital and then it is considered a hybrid loan serving the implementation of large investment projects [11]. Mezzanine capital can, therefore, extend the range of available opportunities for financing a company.

3.2 Research Hypotheses

The aim of this article is to examine the functioning of mezzanine financial instrument in the Polish business environment and verify the following hypotheses:

Hypothesis 1 (H1): The expected result is obtaining mezzanine funds by small and middle sized enterprises.

The theory of hierarchy of sources of funding (pecking order theory) refers to the order of selection of sources of funding. The theory of hierarchy and mezzanine capital characteristics shape the decisions of management boards of companies. Limitation or lack of borrowing capacity mostly affects small and medium sized enterprises. For this respect, the research aims to determine the premises, based on which some of the Polish companies were granted mezzanine funds.

Hypothesis 2 (H2): The expected result is a correlation between net sales revenue and net profit.

Taking into account the characteristics of mezzanine capital, the financial costs tend to increase in the first years of funding, mainly because of the costs of interest, but also due to other charges such as granting fee and annual fee. This results in a reduction of generated profits, which in turn affects the net financial result. Mezzanine financing brings an increase of the scale of business operations and revenues become larger from the moment of obtaining the founding. Thus, in the first years of funding the expected result is an increase of net sale and a decrease of net result.

Hypothesis 3 (H3): The expected result is a negative correlation between net sales revenue and WIG index results on Warsaw Stock Exchange (WSE).

Conducting business operations which are financially supported by mezzanine and the increase of revenue may occur in an economic situation when accessing traditional sources of financing encounters difficulties. The decline of trends in a business environment may manifest itself in a fall of indexes of capital markets.

Hypothesis 4 (H4): The expected result is a negative correlation between current liquidity ratio and debt ratio

The aim of this research is to perform examinations of the company's liquidity at the moment of obtaining mezzanine capital and in the subsequent years. For this respect, it is crucial to develop a long term plan for shaping the company's capital

in accordance with requirements related to the use of mezzanine capital. Due to the above, the expected result is the decrease of current liquidity ratio and the increase of general debt ratio.

4 Methodology of Research

The research was conducted on Polish companies financed by mezzanine capital. The examined period is the first three years of business operation, starting from the first year after acquiring mezzanine capital by the companies and the two following years. This is related to a key aspect of funding, i.e. shaping the company's business situation in the first period after obtaining funding. This is a decisive moment for the further operational functioning of companies. The second aspect is examining the period of three years in circumstances of limited access to financial data. Initially, the research was conducted on companies that took advantage of mezzanine capital in Poland and, later on, it was supplemented with Amadeus financial data base supplied by Bureau van Dijk (Company Information and Business Intelligence).

The research was performed on a group of 11 companies operating in Poland which were granted mezzanine funds and remained active for at least two subsequent years after the acquisition of mezzanine capital. The analysis was based on results obtained after the examination of mezzanine capital, verifications of hypotheses on the size of the financed companies and the estimated correlation of the selected financial data. Moreover, the research also aimed to investigate and link together financial data such as current liquidity ratios and debt ratios in companies acquiring mezzanine capital.

Relationships between the particular sets of outturn data were determined on the basis of Pearson correlation coefficient, and verification of results was based on J. Guilford's classification of interdependence.

5 Research Results

Below the research results are presented which either prove or reject the proposed hypotheses. Initially, the research was focused on mezzanine financial engineering and, later on, the verification of hypotheses was performed.

5.1 Financial Engineering of Mezzanine Capital

The precise study of mezzanine capital in form of a review of the international publications and empirical research were the base for developing a concept diagram

of mezzanine financing (Fig. 3). The diagram has been developed by courtesy of Zaberd S.A. Management Board on the basis of process analysis of mezzanine financing obtained from AMC I fund (Accession Mezzanine Capital L.P.)

The major goal was to obtain mezzanine capital for the purpose of the acquisition of another company. Mezzanine fund provides the company the capital, while the repayment method is based on a flexible program tailored to the company's current financial situation. A part of interest is repaid and the remaining interest and the capital is due at maturity of mezzanine financing. Other interest is shown in accounts; however, they have no impact on current cash flows, which facilitates the development of business operations. Interest was paid in foreign currency, which involved an additional risk related to the exchange rate. The time of investment is usually 7 years. Within this time, the company should achieve the following key objectives:

- organic effect,
- synergy effect,
- activity diversification.

5.2 *Sizes of Companies Acquiring Mezzanine Capital*

The subject of research were companies operating in Poland. Classification of European Commission served here for analyzing the size of companies (Table 1). Following the European Commission recommendations, in order to be regarded as SMEs, entities must not exceed 250 employees nor an annual turnover of EUR 50 million or balance sheet total EUR 43 million. In addition, it is taken into account small companies employ less than 50 people and their annual turnover or annual balance sheet total does not exceed EUR 10 million.[1] Based on the above definition of European Commission, the research on Polish companies which acquired mezzanine capital was conducted. These companies were ranked according to the company size criterion.

Table 2 presents a classification of Polish companies which benefited from mezzanine financing (Table 2). The funding was in most cases obtained by small (18.18 %) and medium-sized enterprises (36.36 %).

Given the research results and verifying the hypothesis H1, the important conclusion is that the SMEs used mezzanine capital in 54.54 % of the cases; however, small companies used it only in 18.18 % of cases. It is worth noting that mezzanine capital was obtained by 45.45 % of large companies. Hypothesis H1 is discarded. Mezzanine is not primarily used as for funding SMEs in Poland. This injection of capital is mostly used for financing medium and large enterprises.

[1]Article 2 of the Annex to the European Commission Recommendation 2003/361/EC.

Table 1 Classification of enterprises according to recommendations of European Commission (*Source* Own elaboration based on Art. 2 in Annex to European Commission Recommendation 2003/361/EC)

Size of companies	Number of employees	Net revenues from sales	Balance sheet total
Small	<50	<10 million euros	<10 million euros
Average	<250	<50 million euros	<43 million euros
Large	≥250	≥50 million euros	≥43 million euros

Table 2 Classification of business entities covered by the research based to the criterion of size

Company size according to European commission—in research group (Poland)	Small	Medium	Large
SHARE in %	18.18	36.36	45.45

5.3 Correlation Analysis

Hypotheses H2, H3, H4 were based on a calculation of the correlation coefficient. Hypothesis H2 took account of the correlation between the income and the net result (Fig. 4).

H2 research (Table 3) proved that in 72.73 % of the cases, at least high or almost full correlation occurred. Therefore, the values of net revenue and net result are strongly related. However, only 25 % of cases within this group displayed negative correlation. The other cases displayed positive correlation. Accordingly, H2 hypothesis is rejected.

Another analysis concerned the correlation of net sales revenue and the WIG index.[2] WIG index quotations were regarded as an average value taken from the index value on the first day of the year and the index value on the last day of the year.

The verification of hypothesis H3 shows a high correlation occurring at least in 54.55 % of the examined cases. Only 16.66 % of the companies within the group had positive correlation. It is worth noting that in 45.45 % of cases the correlation was medium or weak. Within this group 80 % of the cases have shown a positive correlation, which is a result opposite to H3. In this context, the conclusions drawn seem to favor the hypothesis H3, but with a strong remark that this conclusion may be ambiguous (Table 4).

In hypothesis 4 (Table 5), the correlation between current liquidity ratio[3] and total debt ratio[4] was verified. Median of current liquidity ratio in the first year after

[2]WIG—stock index covering all companies listed on the Stock Exchange in Warsaw meeting the base participation criteria within the indexes.

[3]Current liquidity ratio = Short-term receivables/Short-term liabilities.

[4]Total debt ratio = Liabilities and provisions for liabilities/Total assets.

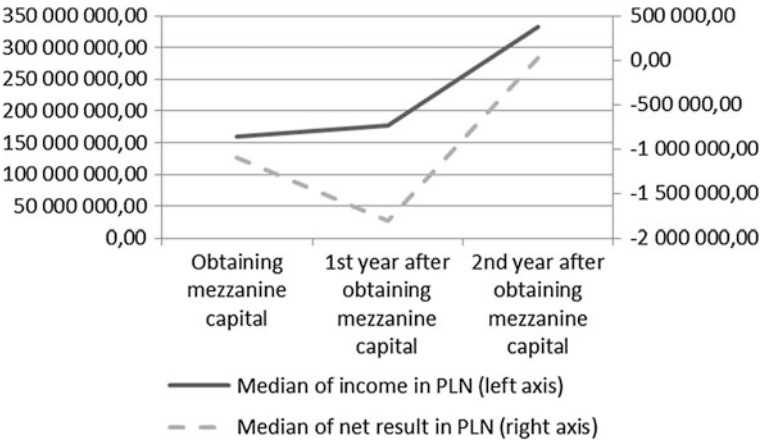

Fig. 4 The median of net revenue and net result in the first years of obtaining mezzanine capital (*Source* Own elaboration)

Table 3 Verification of the hypothesis concerning the negative correlation of net sales revenue and net profit of companies using mezzanine capital (Source: Own elaboration)

Hypothesis 2 (H2) The result expected is a negative correlation between net sales revenue and net profit		
Interdependence classification according to J. Guilford	Share of companies involved (%)	Positive or negative correlation
$\|r\| = 0$ $\|r\| = 0$—no correlation	0.00	–
$0.0 < \|r\| \leq 0.1$—slight correlation	0.00	–
$0.1 < \|r\| \leq 0.3$—weak correlation	27.27	67 % negative and 33 % positive correlation
$0.3 < \|r\| \leq 0.5$—medium correlation	0.00	–
$0.5 < \|r\| \leq 0.7$—high correlation	9.09	100 % positive correlation
$0.7 < \|r\| \leq 0.9$—very high correlation	9.09	100 % positive correlation
$0.9 < \|r\| < 1.0$—almost full correlation	36.36	75 % positive and 25 % negative correlation
$\|r\| = 1$ $\|r\| = 1$—full correlation	18.18	50 % positive and 50 % negative correlation

obtaining mezzanine the capital undergoes depreciation; however, it increases not later than in the second year. Median of total debt ratio goes up in the first year after obtaining mezzanine and holds a similar level in the next year. (Fig. 5)

For 63.64 % of companies (Table 5) the correlation was at least high. Within this group, in all cases the correlation was negative. Therefore, it can be concluded that the hypothesis H4 is confirmed.

Table 4 Verification of the hypothesis concerning the negative correlation of net sales revenue and the WIG index results (Source: Own elaboration.)

Hypothesis 3 (H3) The result expected is a negative correlation between net sales revenue and WIG index results		
Interdependence classification according to J. Guilford	Share of companies involved (%)	Positive or negative correlation
$\|r\| = 0$ $\|r\| = 0$—no correlation	0.00	–
$0.0 < \|r\| \leq 0.1$—slight correlation	0.00	–
$0.1 < \|r\| \leq 0.3$—weak correlation	18.18	100 % positive correlation
$0.3 < \|r\| \leq 0.5$—medium correlation	27.27	67 % negative and 33 % positive correlation
$0.5 < \|r\| \leq 0.7$—high correlation	0.00	–
$0.7 < \|r\| \leq 0.9$—very high correlation	18.18	100 % negative correlation
$0.9 < \|r\| < 1.0$—almost full correlation	27.27	67 % negative and 33 % positive correlation
$\|r\| = 1$ $\|r\| = 1$—full correlation	9.09	100 % negative correlation

Table 5 Verification of the hypothesis concerning the negative correlation of current liquidity ratio and total debt ratio for the companies financed by mezzanine capital (Source: Own elaboration.)

Hypothesis 4 (H4) The result expected is a negative correlation between current liquidity ratio and debt ratio		
Interdependence classification according to J. Guilford	Share of companies involved (%)	Positive or negative correlation
$\|r\| = 0$ $\|r\| = 0$—no correlation	0.00	–
$0.0 < \|r\| \leq 0.1$—slight correlation	18.18	100 % negative correlation
$0.1 < \|r\| \leq 0.3$—weak correlation	9.09	100 % positive correlation
$0.3 < \|r\| \leq 0.5$—medium correlation	9.09	100 % negative correlation
$0.5 < \|r\| \leq 0.7$—high correlation	9.09	100 % negative correlation
$0.7 < \|r\| \leq 0.9$—very high correlation	18.18	100 % negative correlation
$0.9 < \|r\| < 1.0$—almost full correlation	18.18	100 % negative correlation
$\|r\| = 1$ $\|r\| = 1$—full correlation	18.18	100 % negative correlation

After verification of hypothesis H1, hypothesis H4 was developed by comparing current liquidity ratios and total debt ratios of SMEs and large companies which received mezzanine funding (Table 6).

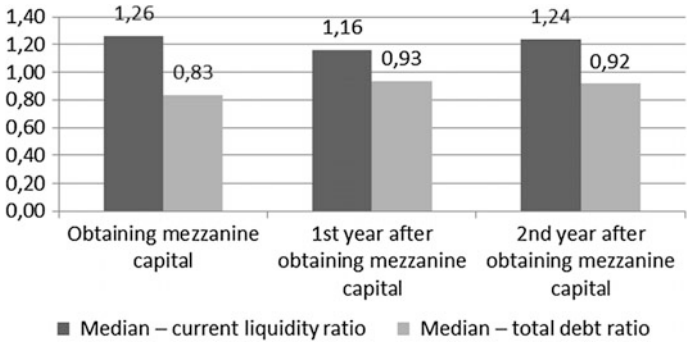

Fig. 5 Median of current liquidity ratio and total debt ratio in particular periods since the moment of acquiring mezzanine capital (*Source* Own elaboration.)

Table 6 Current liquidity ratios and debt ratios for SMEs and large companies—average, variance (Source: Own elaboration.)

	SME companies	Large companies
Current liquidity ratio		
Average	1.08	1.16
Variance	0.36	0.14
Total debt ratio		
Average	0.85	0.90
Variance	0.10	0.02

Considering the index of current liquidity and total debt, it turns out that it is higher for large companies. Therefore, a larger debt can be presumed based on the capital requirements and the actual market position.

6 Conclusion

The article presents and expands knowledge on how mezzanine capital functions in the conditions of Polish economy. The analysis of the use of these funds demonstrates the specificity of conducting business in an economy of a developing country.

Mezzanine financing is available and obtained for businesses of all kinds. Small companies use this method to a limited extent; it most often is utilized by companies classified according to the guidelines of the European Commission as medium and large.

Mezzanine financial engineering amplifies the attractiveness of this type of financing due to its flexible adaptation to the company's individual financial situation. Improvement manifests itself in how interest is paid, which may be

postponed in part or in whole and accumulated with the outstanding capital payable upon the end of the funding period. This does not cause an excessive financial burden or business disruptions. The undertaking may still expand, which is the main factor the investor's involvement, and the company can avoid financial difficulties resulting from the payment of principal and interest as is the case of a regular bank loan. Moreover, from the point of view of enterprises, the additional remuneration for the entity offering mezzanine capital does not result in an excessive dilution of the capital.

The research shows that there is a potential for growth of the mezzanine sector in developing economies, not necessarily by means of following Western patterns, but more often by searching for convenient methods of funding which do not excessively burden cash flows.

The increase in revenues resulting from new investments financed in the form of mezzanine, even despite the increase of expenses, may result in improvement and growth of the net result. Thus, the Mezzanine capital can support the growth of the companies' turnover at a time when the indexes of companies listed on the stock market tends to decline.

An important feature of mezzanine financing is that it modifies the structure of the company's capital, which is characterized by an increased role of the foreign capital, which may contribute to the risk of business operations and cause deterioration of liquidity.

This research, however, is limited in a number of ways. The most difficulties arise from limited or impossible access to sources and databases, mainly for the reason that mezzanine capital is granted almost exclusively by specialized private equity funds, which are closed entities. Collecting information on funding is difficult due to small number of entities keeping statistics concerning mezzanine capital in developing countries, where this type of funding has been available for a relatively short time in comparison to the developed countries. However, despite the obstacles, the study provides a solid base for further development of the research in mezzanine capital. The field of research may be extended to the developing countries from the region of Central and Eastern Europe. Moreover, it may prove important to examine and compare the mezzanine costs in both developing, and developed countries, taking into account the indexes of standard interest rates and PIK.[5] The, however, may be difficult due to the limited availability of data or the cost accessing it.

The research results presented in this study can be useful for entrepreneurs seeking an alternative method of financing or institutions interested in an attractive way of investment with acceptable return rates in conditions of an increasing demand for financing the growth of enterprises.

[5]Pay in kind.

Amadeus Database Bureau van Dijk (Company Information and Business Intelligence)

Annex 1 List of mezzanine capital companies in Poland

List of companies—Mezzanine capital in Poland	
ZTB Zakłady Tłuszczowe w Bodaczowie	Internet group
ZABERD SA	INFO—TV—FM LLC
Wheelabrator	GTS Central European Holding B.V.
Solaris Bus&Coach	CTL Logistics Sp z o. o.
Marvipol S.A.	Kisan
Lux Med.	

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Modelling of Currency Exchange Rates Using a Binary Representation

Michał Dominik Stasiak

Abstract The present article proposes a new method for modeling currency exchange rates in a binary representation, with the exchange rate of AUD/NZD as an example. The binary representation, obtained on the basis of 5-year long tick historical data, is incorporated into a statistical analysis to derive and determine relevant parameters for the model. The model presented in the article makes it possible to approximate the probability of the direction of changes in the currency exchange rate in relation to its preceding changes. The model is characterized by the following features: the independence of its parameters on overriding trends and a possibility of its application to construct automatic prediction systems.

Keywords Foreign exchange market · High frequency econometric · Technical analysis · Currency market investment decision support · Modelling of currency exchange rates

1 Introduction

The currency exchange rate, due to its real time fluctuations, is traditionally displayed on most broker's platforms to describe price movements in the form of a candlestick chart based on time intervals. This particular data representation is also used in a determination of values of appropriate indicators or in technical analysis of the exchange rate of a given currency pair. This article proposes a new approach to the tick data representation based on the absolute value of a change in the price. The basic advantage of such an approach is to eliminate in the technical analysis those periods of time when no fluctuations in exchange rate occur, e.g. nights, but at the same time to retain the information on the direction and level of changes, which, for a potential investor, is essential.

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In this study, the exchange rate in a binary representation was analysed by statistical methods which aimed to examine any possible dependencies between historical data and concurrent changes in the price. In the statistical analysis employed in the study, a set of tests included in the SP800-22 suite [1] was used. The tests are used by, for example, the National Institute of Standards and Technology (NIST), to examine generators of pseudorandom numbers and certify cryptographic modules.

The article presents a method for modelling exchange rates in a binary representation. The state model for binary representation proposed in the article (SMBR) allows the probability of future changes in relation to historical changes to be determined. The examinations were carried out using tick data for the AUD/NZD (Australian Dollar/New Zealand Dollar) currency pair provided on-line by Dukascopy broker for the period of five years (01.01.2010–01.01.2015).

2 Binary Representation of Exchange Rate

Exchange rates are traditionally presented in the form of a candlestick chart (because the candlestick lines resemble candles) for a given time interval. The exchange rate in a required time period is represented by four parameters that form the shape of a candlestick (opening price, closing price, maximum price and minimum price). Such a representation is commonly used by all broker's platforms to visualize changes in currency rates. It is also used as input data by indicators of technical analysis [2–5]. The candlestick representation, being a transformation of tick data into time domain, eventually leads to significant problems in its interpretation. Currency exchange rates are characterized by high frequency of change in time. Exchange rates fluctuate too frequently and often with high amplitude of movement, which, as it occurs, can last for several minutes (e.g. during a presentation of macroeconomic data) or a number of hours, obviously with far lower amplitude, e.g. fluctuations occurring during the night. This particular nature of data to be analysed leads in consequence to high complexity of models defined in the time domain. The exchange rate changes every tick, i.e. about every one second. As a result, to analyse unprocessed tick data means to record and store parameters that, in fact, are irrelevant or have very low relevance, such as the minimum and frequent changes by, for example, just 1–3 pips—noise. It can be assumed that a great number of small changes is purely accidental and has no potentially useful information value. One might then ask a logical question: what level of a change in the exchange rate has a potential information value that can be utilised in analytical modeling of the exchange rate?

In a binary representation, every change in the price by a given value, called discretization unit, can be represented by the value 0 or 1. This form of representation of the exchange rate includes the most essential information from the technical analysis perspective, such as the direction and volume of changes. Figure 1 shows an example of different runs of changes in the exchange rate represented by

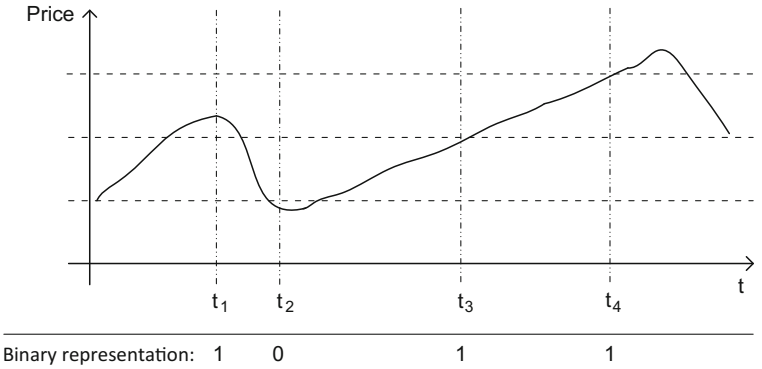

Fig. 1 An example of binary representation of currency exchange rate

the same candlestick. From the point of view of the investor, for whom the value 0/1 represents a solution to the SL/TP (stop loss/take profit) problem, the data in the form of a candlestick chart simply "loses" a large part of vital information.

2.1 Exchange Rate Binarization Algorithm

For the initial value of the exchange rate the binarization algorithm defines the upper and lower limits. These are equal to the positive and negative increments of the exchange rate by a required discretization unit. If the exchange rate falls down below the lower limit, the algorithm assigns the binary value equal to zero (0) to this change, whereas in the case when the price increases above the upper limit, the algorithm assigns the binary value equal to one (1) to the change.

In the following steps, the algorithm determines subsequent boundary values against the concurrent exchange rate. As a result of the operation of the algorithm, the exchange rate of a currency pair can be presented as a binary string, a sequence of 0's and 1's, (e.g. 10101……01111). Figure 1 shows an exemplary conversion of an exchange rate into a binary series.

In the case when price gaps occur, e.g. following week-ends, the algorithm examines which value would have been achieved and returns an appropriate result. Then, subsequent boundary values are determined in regard to the first price following the price gap.

2.2 Comparison of Binary and Candlestick Representations

Let us consider an analysis of exchange rate change at the level of, for example, several dozen, say 30, pips. In the candlestick analysis with the hourly interval, a

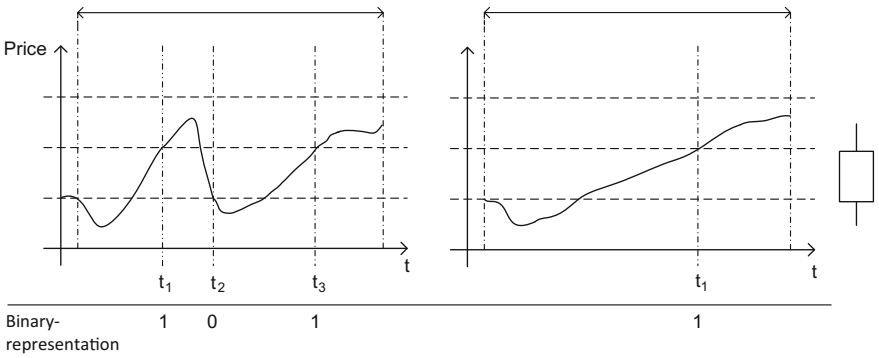

Fig. 2 Two different runs of changes in exchange rate represented by the same candlestick and a different binary representation

number of changes within this range can be represented by just one candlestick and, in consequence, this will effect in a loss of much valuable information pertaining to the frequency and direction of individual movements of the price. Figure 2 presents different runs of changes that are marked by absolutely identical candlestick representation. However, in the case when a binary representation is applied, the most important information for the technical analysis, i.e. the direction and sequence of changes, are recorded, while time is omitted. For an investor, the key information, in particular one that is to accompany a transaction with a limited range where, for example, TP and SL are removed from the price by just several dozen of pips, is the direction of changes (future estimated profit or loss), whereas the duration time of the transaction is irrelevant.

2.3 Evaluation of the Nature of Change in Exchange Rate

The key element in a construction of a binary string representing a change in the exchange rate is a proper choice of a discretization unit. Depending on the adopted value, the obtained run of changes in the exchange rate can have a different nature. A choice of the discretization unit should include practical factors (e.g. those that make concluding transactions in which TP and SL are removed from the price by a discretization unit possible) and the character of the exchange rate of a given currency pair. A choice of a too low discretization unit (e.g. 5 pips) will effect in an inclusion of random fluctuations, the so-called noise (the problem of the existence of noise and its filtration has been widely addressed within the context of technical analysis [6–8]), while a choice of too high values of a discretization unit may lead to a "loss" of an important section of information. Moreover, for large values of

discretization units recorded changes can be very infrequent. The assumption in this article is, after the spread, frequency of changes, etc. being taken into consideration, that the value of the adopted discretization should be roughly 20 pips.

In order to apply a binary representation to model changes in currency rates, the randomness of exemplary series obtained on the basis of historical data was examined. For this purpose, a set of four statistical tests of the SP800-22 suite [1], recommended by NIST, was used. The purpose of this tests was to determine whether the data had random character, i.e. whether the occurrence of subsequent changes was irrespective of the history of the rune. The following tests were chosen: frequency test, runs test, non-overlapping template matching test and long run test. A simultaneous positive result deemed the data to be qualified as random data.

The study was based on the examination of binary series obtained as a result of binarization of tick data of the currency rate for AUD/NZD for the period of 5 years. The significance level adopted for the study was equal to 0.05. The size of the set under consideration exceeded the minimum set—recommended by NIST—with the count of 20,000 elements [1]. Only one test—frequency test—confirmed hypothesis of randomness. Corraboration of the hypothesis of randomness for the frequency test indicates a comparable number of zeros and ones in the period under scrutiny [1, 9]. The remaining three tests reject the hypothesis of randomness, which means that there is a possibility of the existence of certain regularities pertaining to different frequencies in the occurrence for given templates of the zero-one sequences. To sum up this part, one may claim that the results of the statistical tests clearly indicate the existence of a dependence between historical runs and the future direction of changes. [10, 11]. Such a nature of data allows a currency rate in a binary representation to be effectively modelled.

3 Modelling of the Currency Exchange Rate in a Binary Representation

The value of the currency exchange rate is influenced by a large number of factors, such as macro-economic data (e.g. the value of interest rates, etc.), geopolitical situation (e.g. wars) and, difficult to predict, investors' behavior related to psychological and contextual factors that affect individual investor [12, 13]. Quantitative count of all possible factors influencing a currency exchange rate is virtually not feasible. This is why a model for changes in the exchange rate has to be primarily based on heuristic parameters that represent templates of behaviour of investors that have been statistically most frequent. The assumption is that the parameters of a model will be fixed in time and not susceptible to the main trends that rule the market.

3.1 Assumptions and Parameters of the State Model of Binary Representation (SMBR)

Modelling of the exchange rate presented in a binary representation has been based on appropriate definition of states and probabilities of transitions between them. State has been defined as m previous changes in the currency exchange rate. Consequently, the state space is equal to:

$$P = 2^m$$

For example, for m = 2 we get the space that consists of four states: {00, 01, 10, 11}. State 00 indicates that the price has successively fallen down twice by one discretization unit, whereas state 01 informs us that the price has first fallen down and then increased by one discretization unit. States change along with recorded successive changes in the exchange rate (0 or 1). From a given state it is only possible to go to two states. For example, if we are in state 11 (double increase in the price) and a successive decrease in the price ensues—decrease (0), then we go from state 11 to state 10. If, however, the change means an increase in the price (increase), then we still remain in state 11. The adopted model assumes that the sum of all output transition probabilities for a given state is equal to one.

Figure 3 shows a state diagram for the model m = 2. The diagram presents all states and possible transitions between them.

The most important parameter that characterises the state model for binary representation for a specific currency pair is the appropriate values of transition probabilities P (State I, State II) between neighbouring states. These parameters can be determined heuristically on the basis of a statistical analysis of historical data for

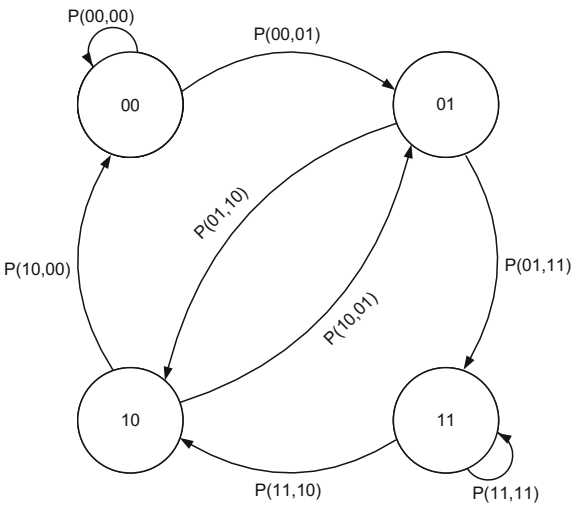

Fig. 3 State diagram for the state model of binary representation for $m = 2$ of AUD/NZD pair

a given currency pair. Observe (Fig. 3) that, for example, from state 11 we can make a transition either to state 11 or 01, hence P(11, 10) = 1 – P(11,11).

The state model of binary representation (SMBR) can be thus described by the following parameters:

- currency pair,
- discretization unit adopted for binary representation,
- the number of analysed historical changes that define state (m),
- transition probabilities for passages between states (P).

3.2 State Model of Binary Representation (SMBR) for the AUD/NZD Currency Pair

In this section a method for modelling of state binary representation for the AUD/NZD currency pair with the discretization unit equal to 20 pips is presented. The state is defined on the basis of two preceding changes (m = 2).

To determine the transition probabilities between neighbouring states, historical tick data for the period of five years transformed into appropriate binary series for the unit equal to 20 pips are used. Table 1 shows the results for the state transition probability for a passage from state 11 to state 10. The number of all observations was divided into 10 successive intervals, each of them with a determined value of the considered probability. Then, in each interval, the average value of the considered probability was determined. The next step was to determine the average value of the transition probability P(11,10) and to establish the confidence interval. Assuming 95 % confidence interval for the t-Student distribution we get the value 63.44 % ± 2.71 %. The obtained result confirms high accuracy of the model.

Table 1 Transition probability P(11,10) in 10 intervals (historical data spanning 5 years)

Interval	Number of transitions	P(11,10)
1	348	0.617816
2	348	0.692529
3	348	0.597701
4	348	0.655172
5	348	0.643678
6	348	0.658046
7	348	0.640805
8	348	0.640805
9	348	0.603448
10	348	0.594828
	3480	0.6344

Fig. 4 Candlestick (week-long) representation of exchange rate of AUD/NZD pair for the period 2010–2015

Figure 4 presents a candlestick chart of the exchange rate for the period of time under scrutiny. It is observable that within this time the exchange rate adopted different overriding trends, while their direction did not have any impact on the relevant transition probabilities in the presented model. This is shown in Table 1 in which one interval corresponds to about a half-year period. In each intervals, the transition probability P(11,10) is characterised by a slight deviation from the average. In the case of the analysis of the remaining transition probabilities, the obtained results are characterised by similar values of the confidence interval.

4 Conclusions

This article presents a probabilistic model based on a binary representation of the currency exchange value for AUD/NZD. In addition, the results of a statistical analysis to determine the nature of changes in the exchange rate for the adopted discretization unit are presented. This analysis confirms a possibility of an existence of certain dependence between historical data and the probabilities of successive changes. The following part of the article presents a state model for a binary representation that makes modelling of the exchange rate of currency pairs possible. The model is versatile in that it be easily applied to model any currency pair. The article includes an example of modelling AUD/NZD currency pair, while future investigations to include other currency pairs are planned. The results presented in the article indicate high accuracy of the model, whereas the transition probabilities obtained by the applied heuristic method are characterized by their independence from current trends on the market. The model is equally applicable to support investment decisions or to construct algorithms for automatic commerce transactions, because it makes it possible to evaluate potentially the probability of profit for transactions with given SL and TP parameters.

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The Factors and Parameters Determining the Formation of the Target Capital Structure in Family Businesses

Maria Malinowska and Danuta Seretna-Sałamaj

Abstract Capital structure management company can be considered one of the most difficult issues in the entire process of business management. Conscious use of available capital, the use of debt capital makes it possible to achieve greater benefits for the owners of the company including family businesses. Decisions on the management structure of finance in the family business have a significant impact on the financial situation and, consequently, the value of the company. Owners of small family businesses do not usually have specialized education of finance, often these companies can not afford to employ qualified staff of financial. According Lewandowska [21] our native companies do not make full use of opportunities created by alternative forms of financing.

Keywords Capital structure · Family businesses · Debt · Financial leverage

1 Introduction

Decisions associated with granting structured finance optimal shape require prior conduct a thorough analysis of many factors, which are characterized by variability both in time and in space. For this reason, the optimal structure is non-financial standing, because it changes depending on the intensity and direction of these factors. The number of factors that influence decisions related to the management target structure of finance is high. The potency of each of these factors, depending on the time and place, is not the same. Assess the needs management company, based on its knowledge of the economic, environmental knowledge and experience. The structure of finance in the branches of the economy is different because

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Table 1 Factors determining the capital structure (Source: Own study based on [2, 7, 9, 15, 19, 20, 24, 26, 30, 32])

Macroeconomic factors	Ickiewicz [15] • factors: economic, legal, technological, political, international
Microeconomic factors	Ickiewicz [15] • competitive environment • factors created by the company itself • on the legal form • the stability of sales • the level of profit achieved • about the structure of assets • about politics and dividend payments • the so-called. the costs of representation Copeland and Weston [32] • the expected growth rate of sales • stability of sales in the future • specific features of the industry • structure of the business assets • control and the ratio of shareholders and management to take risks • the attitude of creditors with respect to the company and the industry Brigham [2] • the risk of business operations • the tax burden • financial flexibility • the ratio of managers to risk Emery and Finnerty [9] • operational risk • market position • margins and other measures of financial results • quality management • conservatism applied accounting principles • the ratio of foreign capital to the liquidation value of the assets • the ratio of the size of the cash flow level debt and its servicing • financial flexibility in the future Levy and Sarnet [20] • the demand for investment funds • the level of current and future profitability • stability of earnings • continuity of dividend payments • attitudes of shareholders and creditors • attitudes of managers • quotation of bonds Timan and Wessels [30] • the share of assets in the capital structure • non-interest tax shields • prospects • unique production • industry classification • size of the undertaking • variability of profit • profitability

(continued)

Table 1 (continued)

	Siudak [26] • the risk of business (operational) companies • taxation of company income tax • the ability to raise capital on reasonable terms disadvantaged • the level of aversion management to incur debts Leland general factors [19] • business risk • taxes • costs of bankruptcy • interest rate risk-free • the amount of dividend payments • issued bonds Norton [24] • capital market • costs of the agency, also known as the costs of protecting the interests • taxation • signaling • asymmetry of information • material factors • management • aiming for management flexibility • labor market Davis [7] • factors specific to the company and • is what will allow him to market
General factors	Leland [19] • business risk • taxes • costs of bankruptcy • interest rate risk-free • the amount of dividend payments • issued bonds Norton [10] • capital market • costs of the agency, also known as the costs of protecting the interests • taxation, • signaling, • asymmetry of information • material factors • management • aiming for management flexibility • labor market Davis [11] • factors specific to the company and • is what will allow him to market

different is the power and influence of factors on the level of debt in a given sector of the economy.

The intensity of study of factors determining the structure of finance is reflected in the rich bibliography, especially foreign language. The authors consider the

problems associated with it in different ways and with varying degrees of detail. Studies on the factors affecting capital structure initiated GJ Hurdle [14].

Table 1 shows the factors affecting capital structure, presented in the literature, both Polish and foreign.

The level of debt the company is conditioned by the action of the many factors that can be divided into micro- and macroeconomic factors. Microeconomic factors affecting the structure of corporate finance are diverse, related to various aspects of the company and dealt with different detail. Undoubtedly a leading position among the microeconomic factors is the cost of capital. With the cost of capital also entails the risk that is inherent to the activities and functioning of the entire company. Apart from the risk and cost, are factors affecting the industry, the structure of assets, age and other companies. Microeconomic factors as the name suggests relate to the company and its surroundings closer. The exact identification of all microeconomic factors is possible when analyzing the factors concerning a particular company.

Macroeconomic factors affecting the structure of corporate finance relate to the economic situation of the country (e.g., unemployment, inflation, GDP) and the stock market. Suitable for entrepreneurs macroeconomic conditions allow for easier use of foreign long-term sources of funding as well as the possibility of issuing securities. Increase funding and better access to them conducive to the development of enterprises. Stable macroeconomic conditions allow you to more easily determine and control the target structure of corporate finance.

2 The Specific Features Financing of Family Businesses

There are many definitions of a family business, one of them is the definition quoted by Luke Sułkowskiego "family business is a business entity in which the majority of the ownership structure and function of management of the entire entity remain in the hands of one family" [28]. The family company has any legal form, the capital of the company is wholly or decisive part in the hands of the family [10]. The family business takes place when at least two family members working in it, exercising control over the management and financial and succession has already taken place or is planned [1]. Family businesses are considered to be a special type of business entities. They have unique characteristics that may represent one side of their competitive advantage and, secondly, that exhibit a factor harmful to their development. This is mainly due to the role of the owner and his family in the process of business management. Characteristics of family businesses in various stages of development are the strength and the source of their success or weakness and cause failure [17]. The characteristics of family businesses include [22]:

- dependence of family ownership of the family business(family involvement in the ownership and management of the company)
- trend to the family of transfer of ownership and/or power,

- family of organizational culture,
- linking targets family and implemented business strategy of the company
- use of family resources, financial, personal, and intellectual

One of the most important traits of entities family is a long-term perspective of business for the next generation. The family nature of these entities makes the durability and stability, and not necessarily to maximize profit or maximize the added value of the main objectives of their business [23, 29].

The main advantages of family businesses in the financial sphere include the conduct of investment policy, the selection of sources of financing and a characteristic way of corporate governance. Family businesses engage their funds mainly in low risk projects without achieving high rates of return in times of economic growth, but at the same time without incurring high losses in times of crisis. The expected payback period is in the case of family businesses usually much longer than non-family companies. Often the investments of family businesses have a 5–10-year time horizon. [18] This is due to the fact that managers are focused on the benefits of investments for future generations as opposed to management companies non familial, whose main objective is to demonstrate the high current results.

An important aspect of the financial management of family businesses is a way to finance operating and investing activities. As research shows, overall debt in this group of companies is lower than in non-family businesses [18]. The main source of financing is equity, mainly share capital and retained earnings [33]. This conservative strategy of financing activities on the one hand is very risky and less costly, but it may slow down the development of the company, especially in periods of economic growth. The consequence of the fact that in family businesses owners deal directly with the management company, the atypical nature takes them a way of exercising ownership supervision. Very rare typical agency costs [33]. But you cannot say that in general do not appear, but rather should emphasize their specific nature. Therefore, it is often difficult to extract the personal assets of the owners of property company, and the financial resources of the company are identified with the resources of the family, the entities of the notes to be more rational approach to managing expenses and costs.

These features have a different degree of intensity in companies and do not always occur together, thereby affecting the heterogeneity of this group of players. The study shows that the further generation of the company, is it accepted a longer payback period [33]. Optimal financing is one of the four main factors in the development of family businesses next: succession planning authority and ownership, professional management and the ability to overcome the negative impact of family conflict on business. Finance family business stands determined uniqueness, which consists of: special logic Financial and resulting from the barrier independence or moderate attitude to foreign funding sources, and which most fully reflected in mature businesses, especially medium and large size, operating on the market for at least a dozen years, corresponding to the period “growing” a new generation [33].

Family businesses are usually older than non-family, and yet reach the lower sales figures. Many of these "increases" slowly, or "does not want" to grow so much and quickly as would be possible using all available sources. After disasters usually start, which made them strong and allowed to survive for a long period, these companies tend to gradually decline, which gives rise to the serious difficulties especially during the transition generation. The cause moderate compared to the growth of the company and the choice of funding sources may be reluctance to incur excessive risks. Owners of family support different approach to the value of the company that makes family businesses are also different in terms of their financial strategies. [27] Personal preference may apply with respect to three related issues the company's growth, the degree of risk incurred and the control properties [13] a business owner. Too cautious attitude to financial risk may result in addition withdraw from making other types of risks, including the risks that development [4, 34].

Aversion to take risks—a high degree of caution relates primarily to financial risks. This is reflected in a much lower level of indebtedness of family businesses compared with no familial and a more restrained use of permanent full-time staff. An unjustified rejection debt capital, it is often voluntary resignation of financial leverage, that is, the possibility of raising return on equity, thereby maximizing the benefits to the business owner. Too careful attitude to financial risk may result in addition withdraw from making other types of risks, including the risks that development [4, 34].

Family businesses have on average a lower capital than non-family and they need financial hardly accept capital market investors: private or public, as well as partners from financial institutions, mainly banks [25]. Another element of the specifics of finance family businesses is a barrier to independence, which is limited in scope and the use of sources of financing, especially external financing, the basis of which, in addition to economic factors, the most common are psychological resistance. Family businesses can benefit from common types of capital, there is no separate, specific and relevant only to those entities funding sources. It states greater efficiency and the ability to use them [25]. Availability of certain funding sources is strongly linked with the process of the development of the company, expressed his size and strength of the influence of family on the management and ownership. For fear of financial risk from a family with extreme caution using a credit or a loan, which is the most popular sources. Willingly, but not without resistance, turn off the credit unconventional forms of financing, such as: factoring, leasing, equity contributions.

On the growth strategies of family firms and their financing decisively influenced by the following factors: the degree of concentration of ownership in the context of the board of the family, the degree of professionalization of the management of a family business, demographic characteristics of owners (their age, education, experience, personality) and the requirements of macroeconomic and specific industry in which the company operates.

Family character (e.g. the ability to quickly mobilize additional financial resources of family) and loyalty, dedication and willingness to sacrifice broader

crew can provide effective protection against the negative influences of the environment, including against major financial crises.

The family company is defined as "a company of any legal form, whose capital is wholly or decisive part is in the possession of the family—the founders, at least one member exercises decisive influence over the management or itself holds a leading position with the intent to permanently maintain the project in the hands of families". Family businesses have on average a lower capital than non-family and they need financial hardly accept capital market investors: private or public, as well as partners from financial institutions, mainly banks [34].

The study shows that the main sources of funding of family businesses is their own capitals, followed by bank loans, EU funds, forms of off-balance sheet, such as e.g. leasing. Own resources supplemented by EU grants and credit and supported by forms of off-balance sheet appear to be essential and sufficient funding methods. Frequent situation in family businesses should reject offers of credit. Their decisions justify the increased risk associated with the use of foreign capital, the desire to have full control over the company and the lack of need for raising additional funds. This is due to concerns about dependence on banks and financial institutions. Family businesses will grow slower but safer and more secure, with all activities under control. The owners of family businesses above assessed the financial security of the family and the company than the benefits of dynamic development and growth of the company.

3 The Criteria for Optimization of the Capital Structure of Enterprises

Availability of different sources of financing on the capital market and the cost of capital affect the structure of corporate finance and the weighted average cost of capital. Family businesses financing investments of debt, must reckon with the fact that increased the risk of such financial decisions. The risk is higher, the higher is the share of foreign capital in the structure of finance. On the other hand, the debt with a low interest rate can increase the market value of the company and the net profit. Published theories and experience allow managers to determine the finance structure, which can be considered optimal, and at which the value of the company often reaches the maximum value that the data in the volatile and often unpredictable conditions can be obtained. Determining the appropriate capital structure of the company including the family is difficult to achieve in practice. Selected approach to the optimal financing structure found in the world and Polish literature is presented in Table 2.

Analyzing Table 2 should be noted that the main criterion for providing an optimal capital structure is the value of the company and increase the wealth of the owners. This objective can be achieved by maximizing the capacity of the debt, taking into account the cost of capital and risks financial statements.

Table 2 Management of target capital structure (Source: [3, 5, 6, 8, 11, 16, 31])

Copeland et al. [6]	They recommend the use of three interconnected ways • estimate as much as possible present capital structure of the company based on market values • assessment of the capital structure of comparable companies • assessment of overt and covert methods of financing used by the company management and their impact on the target capital structure
Bielawska [3]	Optimal capital structure is one that • maximizes the market value of the company • maximizes the return on equity invested in the company • efficiently as possible to retain the ability to pay • minimizes operating costs • efficiently as possible reduces the risk, both financial and operational
Urbańczyk [31]	The target structure is one that allows you to maximize the market value of the company (total market value of equity and debt)
Brealey and Myers [5]	The optimal capital structure is considered at which the WACC is the lowest. Minimizing the weighted average cost of capital is tantamount to maximizing the value of the company
Janasz [16]	The optimal structure of finance is a kind of compromise between the increase in benefits and increased risk
Gajdka [11]	The optimal finance structure associated with the issue of the capacity of the company's debt, which is the maximum size of the debt that it can drag on effective capital market
Donaldson [8]	Means the size of the debt optimal from the point of view of maximizing income owners. This is the amount of debt that does not result in a sudden reduction of net profits and the value of future cash flows generated by the company

Management of the capital structure the company is to maintain the appropriate balance between equity and debt. According to the "golden rule of balancing 'assets should be fully covered by equity. External funds involved in the financing of fixed assets they give rise to the risk of insolvency of the company. On the other hand, the use of debt increases the rate of return on equity (ROE). The method of financing activities current and investment company depends on many factors, and appropriate choice of financing co-creates his success. The financial structure of the company is one of the factors contributing to the current financial performance of the company and the profitability of ongoing development projects. the property company is financed from various sources. Strategic decisions in this area relate to the optimization level of debt. By optimizing the capital structure must take into account:

- long-term goal of the company,
- risk
- interdependence between the activities of current and development,
- a proper assessment of the relationship between the effect of leverage and cost of capital,

- the ability to modify the financial strategy due to changing economic conditions, social, economic,
- financial reserves as neutralizers risk
- financial flexibility,
- load the company tax (interest lower tax base)
- the requirements of investors (shareholders, shareholders).

The optimization of the structure of finance can only speak in relation to a particular company, but it is difficult to suggest an optimal structure for all companies. Determining the optimal structure for the company finances is an internal matter of the company and is an expression of management's financial policies and implemented financial strategy. The decision on the structure of finance considered optimal reflects the result of a compromise between risk and expected rate of return and the impact of a number of factors [35].

The universal method of determining in practice the optimal capital structure of the company, despite the multilateral work carried out by practitioners and theorists in the field of financial management, has not yet been developed. However, there are different variants for determining the structures that can be used in practice [12].

4 The Instruments and Measures of the Quality of Management Structure Finances of the Family Business

Making decisions on capital structure requires the use of different tools and techniques of finance. Financial decisions then become more rational and conducive to strengthening the market position of family businesses.

The main and essential tool that allows you to determine the appropriate proportion of the use of the equity and debt, is the financial leverage. Financial decisions with regard to financial leverage calculated on the basis of balance sheet data, and its impact on EPS allow the use of methods of EBIT-EPS, which allows determination of the equilibrium between alternative financial plans (own financing, debt). All of these tools will be presented on the example of a family business Przedsiębiorstwo Produkcyjno-Handlowe Grześ sp. z o.o, which has its seat in Nysa in the Opole province.

4.1 Financial Leverage

Financial leverage effect on return on equity. The result of financial leverage is an increase or decrease in operating profit. To experienced a positive effect of financial

leverage—the value of operating profit to be achieved by the company should be greater than the product of interest rate debt (loans and loans), and the total value of invested capital.

Results of this study indicate that the highest degree of financial leverage there in 2008 and 2009 DFL = 1.1 The lower level DFL in 2010 and 2011 means lower financial risk compared to 2007–2009 but much lower ROE.

4.2 Analysis of the Relationship of EBIT-EPS

Determination of the optimal capital structure using the method of EBIT-EPS should be carried out three stages, performing the analysis of the impact of the leverage on EBIT and EPS, analysis point of indifference and an analysis of the impact of capital structure on the share price and the cost of capital.

The first and essential step in the analysis of EBIT-EPS is to establish the so-called. point of indifference. The point of indifference is also referred to as the critical point or equilibrium level between alternative financial plans. This is the point, which indicates the level of sales, in which the EPS will remain the same, regardless of whether the company is in debt, or only the equity.

Identifying the point of indifference is important to establish the structure of capital. When EBIT exceeds the point of indifference, a higher level of EPS is achieved with a greater use of debt. When EBIT is below the point of indifference, a higher level of EPS is achieved with less external power supply.

The method EBIT—EPS is a practical tool used to evaluate the impact of alternative plans for financing investment, profits per share under different business income, as measured by operating profit. It is used to determine the optimal capital structure, which company bears the smallest overall cost of capital (Table 3).

Using an analysis of EBIT-EPS, you should be aware that external financial power is double-edged sword. It can increase profits, but can also result in losses. EBIT-EPS analysis helps managers examine the financial impact of various financing methods and choose the right strategy from the point of view of efficiency of the investment [34].

In order to show the feasibility of the method of EBIT-EPS in this paper, the method of EBIT-EPS to analyze the structure of the finances of the family business PPH Grześ sp. z o.o.

Table 3 Degree of financial leverage for PPH Grześ sp. z o. o

The years	2006	2007	2008	2009	2010	2011
Total debt ratio (%)	18	17	16	20	25	18
ROE (%)	–3	1	6	6	–9	–1
DFL	0.99	1.00	1.01	1.01	0.85	0.60

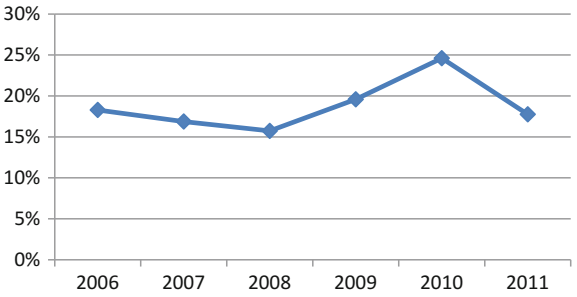

Fig. 1 The debt ratio of the company PPH Grześ sp. z.o.o

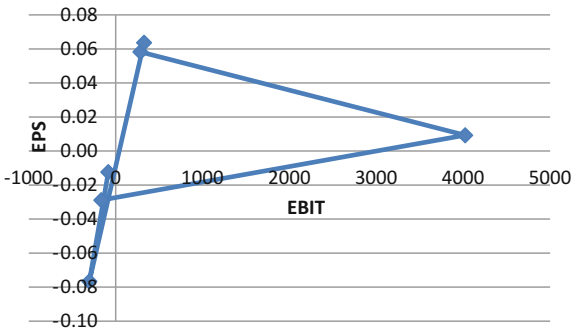

Fig. 2 Dependence of EBIT-EPS for PHU Grześ sp. z. o.o

The Company holds 46,524 shares held by the family, pays 19 % income tax and is considering two options for financing an investment project worth 1 million zł:

- increasing the share of family 10 thousand. shares at 100 zł for participation,
- take out an investment loan bearing interest of 10 % per annum.

Total debt ratio of the company Grześ within 6 years was at a similar level and changed from 16 to 25 %, most of it was short-term financing (Figs. 1 and 2).

To choose the option of financing the investment project of the company Grześ should determine the point of indifference EPS (Table 4).

The point of indifference occurs at the level of EBIT 57,005.37 zł. If the company predicts higher operating profits than 57,005.37 zł it is better to take a

Table 4 Determination of the point of indifference EPS

Financing with equity (issuance of 10 thousand. of family shares 100 zł)	Debt (credit for the amount of 1 million zł interest-bearing 10 %)
$\frac{(\text{EBIT}-\text{I})(1-\text{T})-\text{PD}}{\text{S1}}=\frac{(\text{EBIT}-\text{I})(1-\text{T})-\text{PD}}{\text{S2}}$	
$\frac{(\text{EBIT}-0)(1-0{,}19)}{46524\ \text{pcs.}+10000\ \text{pcs.}}=\frac{(\text{EBIT}-100000\ \text{zø})(1-0{,}19)}{46524\ \text{pcs.}}$.	
EBIT = 57005,37 zł	

loan, below the level of equity financing is more profitable in terms of EPS and incurred financial risk. Like any technology supporting decision-making and financing as a method EBIT-EPS has limitations. EBIT-EPS method focuses on maximizing profits and not on the income shareholders. There may be a positive relationship between these objectives, however, the use of EPS as to maximize ignores the risks and only allows its assessment by generalizations [35]. To select the best capital structure must take into account the trade-off between profit and risk, represented by the threshold of financial viability.

5 Conclusions

One of the factors influencing to the current financial performance of the company and the profitability of ongoing development projects is the capital structure of the company. Financial leverage and the risk of insolvency (bankruptcy) underlie optimize the level of debt. The optimal capital structure is the one that allows for a balance between risk and rate of return on equity, and thus optimizes the price equity. The use by the management of the family business of various types of financial operations changing the existing structure of corporate finance may also be an important element in the process of maximizing enterprise value and benefits for family members.

Theories of shaping the optimal structure of corporate finance are relatively little known in comparison with other aspects of financial management of family firms and rarely reported in the national literature on family businesses. In most cases, the Polish family businesses long-term financial decisions are taken in a subjective manner not supported by detailed analysis of companies and the environment. It is necessary to use tools for managing the structure of corporate finance of family because of the financial benefits.

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Part IV
Models of Organization

Measurement of a Hierarchy as an Organizational Structure Feature

Katarzyna Tworek, Marian Hopej and Janusz Martan

Abstract The main purpose of this paper is to present the concept of a fairly comprehensive measurement method for hierarchy, taking into account, among others, the intensity of inferiority—superiority relation, neglected in the literature. The key finding is that there is a need for the more comprehensive understanding of hierarchy (that includes the hierarchy of power). There is also a need for a measure that will allow the analysis of the hierarchy, which is understood in this way. New hierarchy concept is proposed based on expert knowledge. The hierarchy measure is formulated using mathematical and expert knowledge. The proper reaction of this measure for common hierarchy changes is verified using case study. The proposed measure is verified using case study analysis to validate its usefulness. This paper presents the basic idea and overview of the hierarchy concept and measure and is the first step in the process of verification.

Keywords Hierarchy measure · Hierarchy complexity · Hierarchy of power · Organizational structure

1 Introduction

The hierarchy in the broadest sense is a system of "…some arbitrary elements - things, events, assessments. etc., each of which, on the basis of some established rules, is a subject to a number of classes, called levels; each class has an inferiority - superiority relation with other classes…" [8]. Referring the hierarchy to the organization, it can be assumed that it is a specific system of inferiority and superiority

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of its components, determining who to who is a subject, what is the power and what type of responsibility is connected with it.

The need to define the inferiority—superiority relation in the organization has two reasons. The first reason is the universal principle of limited span of control, valid in organizations of various sizes, regardless of their internal and external conditions [9]. The second reason is the need to create institutions equipped with the authority to solve problems in the field of cooperation between members of the organization. By building a hierarchy, it is possible to determine who has the ability to ultimately decide on contentious issues, and often, what are those issues [9].

Hierarchy (in a narrower sense) is often understood as one of the dimensions of the organizational structure (Hierarchy as a characteristic structural solution is mentioned by [1] and [2], among others). It means that one can talk about two of its features (Fig. 1). One of them is the construction (shape) of hierarchy, which, depending on the observance of the unity of command principle, can be single-line (the principle is respected) or nonlinear (unity of command is abolished). It may also vary in width and height (hierarchy flat or slim).

The second feature determines the distribution of powers between different levels of decision-making hierarchy, describing internal power structure in the organization. In other words, each separate executive position has some decision-making powers with the formal responsibilities [9].

It is not difficult to note that such an understanding of the hierarchy differs from what is usually written in the literature. That is because it is understood in a broader way. It is a synthesis of the two typical dimensions of the structure, i.e. configuration (hierarchy of structure) and centralization (hierarchy of power) (those dimensions are mentioned by Mintzberg [6] and Mrela [7], among others). According to the authors of this article, it is justified by the fact that:

- the internal structure of power can not be determined without taking into account how the hierarchy is built;
- the inferiority—superiority relation is always based on some kind of power that is expressed in the organization, perhaps primarily, as a certain extent of a formal decision-making powers and responsibilities.

In other words, the hierarchy and centralization are linked. Expanding the hierarchy seems to be accompanied by decentralization, and slimming the hierarchy —by centralization.

In the literature, the prevailing view is that the construction of the hierarchy is relatively easily subjected to the measurement. Many measures are used to describe it, examples of which are summarized in Table 1. However, each of them has a fragmentary character and measures only one feature of the hierarchy (shape).

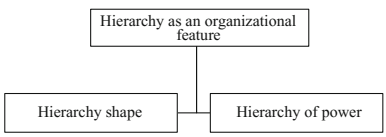

Fig. 1 Hierarchy as an organizational feature

Table 1 Examples of hierarchy shape measures

Name	Description
Height	• The number of levels in most hierarchically developed organizational unit, • The arithmetic mean of the number of hierarchical levels in individual organizational units
Width	• Span of control of chief manager • The number of members of the collective leadership of the organization • The average span of control $r_p = \frac{r_1 + r_2 + \cdots + r_n}{n}$ r_i—average span of control on *i*-th level n—number of levels
Relations between the positions	• The ratio of the number of managerial positions to the number of executive positions • The ratio of the number of ordnance positions to the total number of positions • The ratio of the number of managerial positions to all positions

Source based on [3, 5]

With regard to the second feature of the hierarchy (hierarchy of power), the measure of distribution of power between levels of decision-making hierarchy proposed by Pugh [9] is undoubtedly a successful attempt. The authors have identified 37 universal decision-making situations and established their distribution in various hierarchical levels. They were numbered in a specific way: the lower the level, the higher the obtained number (assuming division of the organization into 4 levels). The measure of the division of power is the value obtained from the following formula:

$$C = \sum_{i=1}^{37} s_i \times k \tag{1}$$

where:

s_i - number of decisions

k = 1, 2, 3 or 4 - depending on decision importance.

This method can be accused of to narrow view on how to share decision-making power (the degree of centralization), which depends, after all, not only on the number of decisions at each level (one decision is not equal to another, and the range of their influence is not the same). However, it is still mentioned and updated in the literature.

These considerations would seem to indicate that the hierarchy is, on the one hand, the important characteristics of a structure, also because regardless of whether someone likes it or not, the world of the organization is naturally structured in a hierarchical way, and, on the other hand, proposals for its measurement are not clear. The purpose of this article is to present the concept of a fairly comprehensive measurement method for hierarchy (in the sense illustrated above), taking into

account, among others, the intensity of inferiority—superiority relation, neglected in the literature. It is based on the concept of the fractal tree.

2 Measurement of Hierarchy

Measure of hierarchy (shape) complexity was presented in earlier work of Tworek et al. [10]. The idea behind the measure was the assumption that organizational hierarchy is treated as a fractal tree. On the whole structure (fractal tree), partial fractal trees were isolated, with the length of the line connecting different levels of the hierarchy corresponding to the span of control. Then, the value of fractal dimension was determined for each partial tree. The measure of the hierarchy complexity is the value of the fractal dimension of the analyzed tree, which is the sum of the average values of the dimensions of partial trees for a given level [3].

Based on this idea, the measure of the hierarchy complexity was proposed:

$$D_S = \sum_{i=1}^{m} \frac{\sum_{i=1}^{m} \frac{\ln x_{i,j}}{\ln s}}{n} \tag{2}$$

where:
m - number of hierarchy levels,
i - number of specific hierarchy level,
n - number of fractal trees on a specific hierarchy level,
j - number of specific fractal tree on a hierarchy level,
s - intensity of inferiority—superiority relations (one value for entire structure),
$x_{i,j}$ - span of control in the organizational unit[1] which is a typical fractal tree,

Figure 1 shows an example of an organizational structure divided into partial fractal trees, with calculated i, j, $x_{i,j}$ values.

2.1 Modified Method of Hierarchy Measurement

It should be noted that the method will correctly indicate the increase of hierarchy complexity in each case and describe the complexity of the hierarchy (as a whole concept presented in the first part of this article) only after changing the formula presented above. It should be changed in a way that takes into account the ratio of the intensity of the inferiority—superiority relation of each organizational unit separately—describing the complexity of the hierarchy of power.

[1]An organizational unit is understood here as part of an organizational structure consisting of a manager and his immediate subordinates (extracted at specific level of hierarchy), illustrated by specific fractal tree.

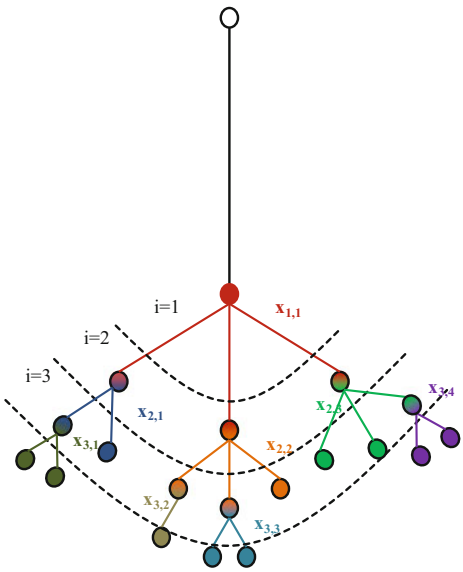

Fig. 2 Measurement of fractal complexity of hierarchy

Without this change, the measure does not respond correctly to all changes in the organizational structure. As an example, two structures are shown on Fig. 2, differing in one organizational unit (containing two positions). It is clear that in the case of adding an organizational unit with the same span of control as those already existing, the measure does not indicate correctly that there has been an increase in the hierarchy complexity (in both cases the hierarchy complexity is calculated as 1.89).

To include the way of understanding hierarchy indicated in the first part of the article and overcome these inconsistencies in the existing formula, it has been amended as follows:

- the weight assigned to each inferiority—superiority relation for each organizational unit separately is added,
- to properly take into account the role of those weights in the final result, the use of the arithmetic mean was abandoned and it was replaced by a cumulative method—the sum of the complexity of individual organizational units at all levels.

In this way the specific weights of inferiority—superiority relations have a crucial role in determining the impact level of the specific organizational unit complexity on the complexity of the entire hierarchy. After the amendments, the hierarchy measure (both its shape and the hierarchy of power) is described by the following formula:

$$D_s = \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{\ln x_{i,j}}{\ln R_{i,j}} \tag{3}$$

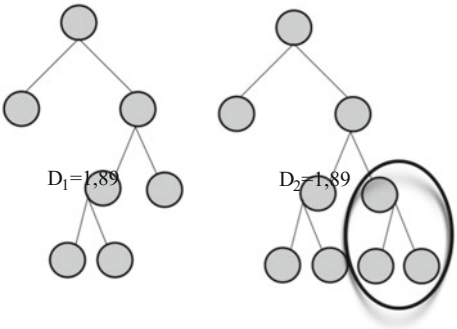

Fig. 3 Comparison of two organizational structures

This means that when in the case shown in Fig. 2 the inferiority—superiority relations with appropriate weights will be added, different values of hierarchy complexity measure will be obtained (as shown in Fig. 3).

The question arises: how weights should be assigned to each inferiority—superiority relation? In this article, it is assumed that their intensity depends on the distribution of power (authority), i.e. the greater the freedom of decision-making and behavior among subordinates (the lower the power of a direct superior), the lower the intensity of hierarchical relation. Conversely, the less freedom of decision-making and behavior, the more intense the relation.

It is also assumed that the freedom of decision-making and behavior of subordinates depends on the scope of the formal power (authority) of a direct superior. The level of remuneration is most probably the simplest measure of that. This means that the higher the salary, the more intense the hierarchical relation (and, conversely, the lower the salary, the less intense the relation).

Of course, the amount of manager's remuneration depends not only on the scope of formal power (authority) assigned to the occupied position. Different factors are also possible, some of them very subjective. However, it seems to be erroneous to believe that the deployment of decision-making power in the organization is not at all correlated with the structure of wages. If such a situation actually took place, it would be an undoubted example of organizational pathology.

2.2 Measurement of Hierarchy—Case Study

The illustration of proposed measure use is a case study of two companies operating in the construction industry in Poland. One of them (A) operates for 18 years and employs 21 people while the second (B) operates shorter (8 years) and is smaller (15 employees). In the first of them, the chief manager focuses the attention on solving the problems of strategic importance, while at the same time chief manager and owner of second organization (B) is not only concerned with strategic decisions but also personally performs work in the area of core activity.

On the basis of the salary levels of individual managers, the weights were determined. 100 % was calculated as the sum of all the salaries of all managers in every organizational unit (somewhat equal to a sum of the power in the organization). The weight is assigned to a given organization unit adequate to the level of salary of its manager ($w_{i,j}$%) as follows: $R_{i,j} = (100\ \% - w_{i,j}\%)/10$. Such a method of assigning weights is dictated by the following considerations:

- The formula $\ln(R_{i,j})$ is in the denominator of the hierarchy complexity measure, and, therefore, the greater is the value of this formula, the smaller is the impact of the complexity of this specific organizational unit on overall hierarchy complexity. For this reason, it was necessary to revers the proportion in such a way that the weight is decreasing with the increase of salary level of the unit's manager.
- The formula $\ln(R_{i,j})$ is compared (by arithmetical operation: division) to $\ln(x_{i,j})$ dependent to the span of control in a given organizational unit. Unification of the magnitude of $R_{i,j}$ and $x_{i,j}$ is necessary for the overall hierarchy complexity measure to be described by the values greater than one (as is customary in the case of almost all measures). For this reason, the resulting percentage in the formula is divided by 10.

The level of salary and the resulting weight assigned to each individual organizational unit are shown in Table 2. Company A can be given as an example of calculations. The total amount of salaries of all the managers in Company A is 72600PLN, a salary of the manager at the second (from the top) level of hierarchy ($x_{2,1}$) is calculated as 83 % * 20.000 = 16,600 PLN. So this is 27 % of the all salaries amount. Thus, it is a basis for calculating the weight for this unit: $R_{2,1} = (100\ \% - 23\ \%)/10 = 7.7$.

Table 2 Level of weights for companies A and B

Number of organizational unit	Span of control	Level of salary [PLN]	Level of salary [$]	% sum of managers salaries (%)	Weight
Company A					
$X_{1,1}$	2	20,000	5000	28	7.2
$X_{2,1}$	3	16,600	4200	24	7.6
$X_{3,1}$	5	12,000	3000	16	8.4
$X_{3,2}$	5	12,000	3000	16	8.4
$X_{3,3}$	5	12,000	3000	16	8.4
Company B					
$X_{1,1}$	2	27,000	6800	49	5.1
$X_{2,1}$	2	13,500	3400	24	7.6
$X_{3,1}$	5	8100	2000	15	8.5
$X_{3,2}$	5	6750	1700	12	8.8

Source own work

On the basis of those weights (Table 2), the hierarchy complexity of both structures was calculated (as shown in Table 3, Fig. 4). The company's A hierarchy complexity is DA = 3.15, and Company's B is DB = 2.27. On this basis, it can be concluded that the hierarchy in the Company A is much more complex then in Company B. Such a large difference is due primarily to differences in the structure of decision-making power. In the company A, a large portion of decision-making power (and hence the authority) is transferred to the 2nd and 3rd (from the top) level of the hierarchy. This is reflected in the level of salaries on these levels (as shown in Table 2). Because of this, the higher weight of the superiority—inferiority relation is assigned to the units on this level in the company B. Therefore, the complexity of the sample organizational unit from 2nd (from the top) level of hierarchy in the Company A is $x_{2,1} = 0.54$ (span of control: 3), and in the Company B it is only $x_{2,1} = 0.42$ (span of control: 2). This example clearly shows

Table 3 Hierarchy complexity of companies A and B

Number of organizational unit	Span of control	Organizational unit complexity	Hierarchy complexity	Weight
Company A				
$X_{1,1}$	2	0.3511	**3.16**	7.2
$X_{2,1}$	3	0.5417		7.6
$X_{3,1}$	5	0.7562		8.4
$X_{3,2}$	5	0.7562		8.4
$X_{3,3}$	5	0.7562		8.4
Company B				
$X_{1,1}$	2	0.3418	**2.27**	5.1
$X_{2,1}$	2	0.4254		7.6
$X_{3,1}$	5	0.7520		8.5
$X_{3,2}$	5	0.7400		8.8

Source own work

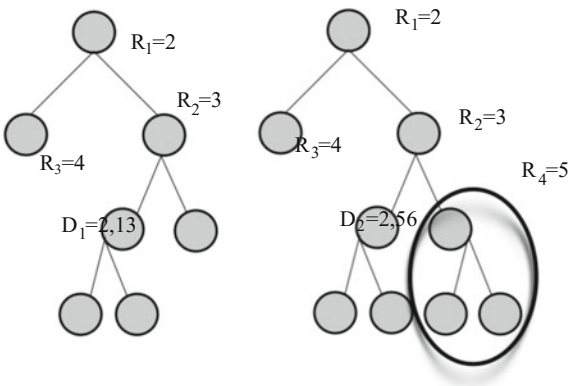

Fig. 4 Comparison of two organizational structures using modified measure

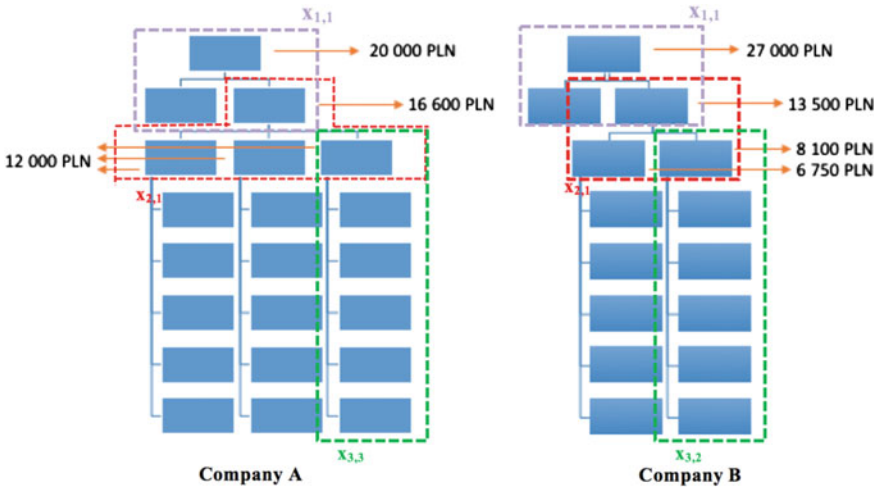

Fig. 5 Organizational structures of companies A and B with salary levels and unit examples marked

that the modified method allows the differentiation of the organizational hierarchy, not only because of the number of hierarchical levels and span of control (as previously presented measure of hierarchy) but also because of the location of power in the organization (Fig. 5).

3 Conclusions

The presented method of measuring the organizational hierarchy is based on a broader than usual understanding of hierarchy. It refers not only to the shape of hierarchy but also to the hierarchy of power. This means that the measure takes into account both height and width of the hierarchy and also the distribution of decision-making power, which undoubtedly has an effect on the intensity of the superiority—inferiority relations. It should be emphasized that the hierarchy complexity measure allows the comparison of the various structures. Single number indicating the complexity of specific hierarchy (shown in this article) has no physical interpretation.

As it seems, the measure can be used to study the organizational structure, for example during the structure simplicity studies. Simplicity is perhaps the most important feature of the structure as a whole. The structure should be in fact the simplest possible, including the least complex hierarchy [4]. Therefore, it is reasonable to ask the question about the factors influencing the simplicity of the structure. The answer to it requires, among others, measurement of a hierarchy of different organizations.

It appears to be less important in manager's work, but it can not be ruled out that one of hierarchy features may be useful in operations management. Measurement of the distribution of decision-making power using salary of specific managers can be this useful tool. It can give the basis for improvement actions in case of structural arrangements and in the field of human resources management.

Therefore, it can be concluded that there is indeed a great need for an objective measure of hierarchy complexity (understood as a shape of the hierarchy and hierarchy of power) and the measure presented in this article can be considered as such.

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Creative Thinking in Management of Disruptive Technologies

Aldona Małgorzata Dereń and Jan Skonieczny

Abstract The article presents creative thinking as a construct determining development of disruptive technologies. This construct consists of three elements: innovative thinking, design thinking and strategic thinking. The notion of creative thinking is understood as the organisation's ability to solve problems from different perspectives, with the use of knowledge, intuition and reason, and as a result getting a fresh look at their substance. Thinking understood in this way allows for generating a breakthrough solution that does not constitute a solution directly resulting from the commonly accepted and recommended paradigm.

Keywords Disruptive technology · Innovative thinking · Creative thinking · Strategy thinking · Design thinking · Process

1 Introduction

In order to achieve and maintain a competitive advantage, contemporary companies need disruptive innovations. The notion of "disruptive innovation" was introduced by Christensen [1], who considers them to be simpler and cheaper technologies and solutions; they generally provide relatively smaller, rather than larger profits. These are innovations that are usually subject to market rules, at first on emerging markets or markets of low significance. It is typical of these innovations that even the most profitable customers of top companies generally do not want to—and in fact are even initially unable to—use products based on such technologies. While developing the ideas of disruptive innovations, C.M. Christensen together with J. Dyer and H. Gregersen have suggested an innovator's DNA model, namely the code of

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generating innovative ideas. The authors have classified the innovators, dividing them into the following categories: entrepreneurs founding new companies, corporate entrepreneurs, product innovators and process innovators.

All of the mentioned groups of innovators, despite differences in their attitude towards creativity and finding solutions to problems, are linked by a common code of generating innovative ideas. The model proposed by the authors consists of three elements: courage to introduce innovations (questioning the status quo and taking risks), behavioural skills (questioning, observing, establishing contacts and experimenting), and the cognitive ability to synthesise new information (associative thinking). In our opinion, the proposed model can be supplemented with one more cognitive ability, which we call creative thinking. This notion is understood as the organisation's ability to solve problems from different perspectives, with the use of knowledge, intuition and reason, and as a result getting a fresh look at their substance. Innovative thinking understood in this way allows for generating a breakthrough solution beneficial in a given situation, rather than the commonly accepted, recognised and recommended solution from the adopted paradigm.

2 Creative Thinking

The innovator's DNA model, namely the code of generating innovative ideas by C.M. Christensen, J. Dyer and H. Gregersen relating to disruptive innovations, is essentially based on two types of skills: behavioural skills and cognitive skills. Behavioural skills include such actions as [2]:

- questioning—innovators seek breakthrough solutions, ask questions that would help them understand how things look and how they may be changed and improved; the posed questions lead to new observations, connections, opportunities and lines of action;
- observing—taking a careful look at the surrounding world—customers, products, services, technologies and companies; such observations give a full view of the situation and ideas for new modes of operation;
- establishing contacts—innovators devote their time and energy to search for and test ideas among a wide group of people representing various environments and various outlooks on the world; instead of customary social relations, they seek new ideas by talking with people, who can offer radically different points of view;
- experimenting—innovators constantly try out new experiences, test new ideas and explore the world mentally and empirically, verifying various hypotheses; they visit new places, try out new things, seek new information and experiment in order to learn something new;
- associative thinking—cognitive skills of innovators, based on associative thinking; innovators synthesise and give meaning to new information, cross link

seemingly unrelated questions, problems or ideas, discovering new lines of action.

While we notice the cognitive and utilitarian qualities of the proposed model, we can also see its disadvantages. In our opinion, the authors of the innovator's DNA model too heavily focus on the ability to generate an innovative idea, ignoring the execution side of the idea, which requires, first of all, creative actions. As stated by Thomas Edison, genius is 1 % inspiration and 99 % perspiration, and we add—perspiration from creative work. Furthermore, we believe that the authors too heavily stress associative thinking in the process of creating disruptive innovations. Certainly, we do not negate the phenomenon referred to as "the Medici effect" [3], but we believe that innovative creative thinking is necessary as the basic cognitive ability. Innovative thinking implies work of innovators, helping them to organise the ideas, which form disruptive innovations.

The model of generating disruptive innovations proposed by us contains a characteristic supplement, in the form of an element, which we call creative thinking, understood as the organisation's ability to solve problems from different perspectives, with the use of knowledge, intuition, reason, and as a result getting a fresh look at their substance. Creative thinking understood in this way allows for generating a breakthrough solution beneficial in a particular situation, rather than the commonly accepted, recognised and recommended solution from the adopted paradigm. The process of creative thinking includes:

- determination of the goal and assumption of values [4];
- identification of the problem and the present possibilities to solve it;
- analysis of the previously developed ideas—analysis of opportunities and threats;
- critical evaluation of the methods to achieve the goal and values;
- obtaining new knowledge (data, information, knowledge)—knowledge accumulation;
- reformulation of the old knowledge and stimulation of new thoughts and ideas;
- in-depth reflection on and broader perception of reality;
- development of an ordered set of activities and formulation of new concepts;
- finding an effective way to solve the problem (dominant concept).

Creative thinking consists of:

- innovative thinking;
- design thinking;
- strategic thinking.

Figure 1 shows elements comprising the scope of the notion of creative thinking and their impact in the process of organisation management. Such thinking enables creation of disruptive technologies (innovations), which allow for obtaining competitive advantage and further development of the organisation.

Innovative thinking is understood as the organisation's ability to understand the examined situation differently, to look at each problem from different perspectives

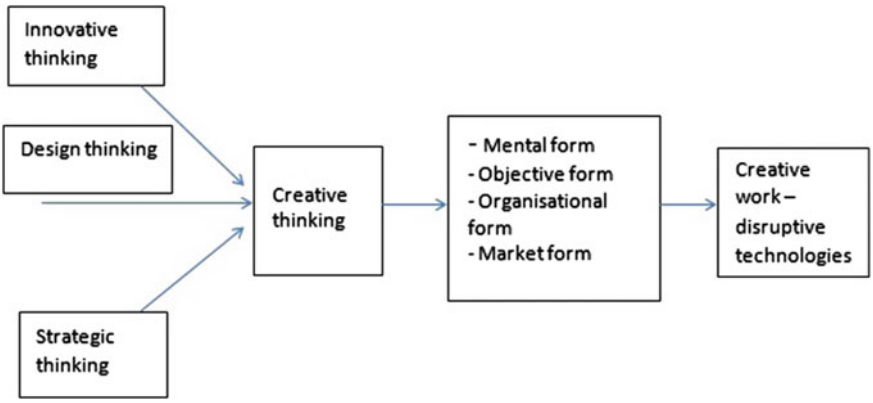

Fig. 1 Innovative, design and strategic thinking as elements of creative thinking in organisation management (*Source* prepared by the authors)

and get a fresh look at their substance. It allows for generating a new solution that is favourable (fitting) in a given situation, rather than merely accepting commonly recognised and usually recommended solutions. Innovative thinking includes:

- generating new ideas, concepts and business models;
- monitoring the existing, competitive and breakthrough solutions;
- transforming and developing the generated ideas into ready market solutions;
- implementing and introducing the prepared solutions to the market;
- openness to the emerging new and previously unknown ideas, concepts and modes of action;
- adapting new solutions, generated beyond the organisation;
- undertaking actions and projects in new market areas;
- patenting and protecting intellectual property of the new solutions;
- constantly improving and developing organisation potential, focused on generating new ideas and solutions;
- eliminating factors constituting a barrier in generating new ideas and solutions.

The second mentioned element of creative thinking is design thinking. According to T. Brown, design thinking is a methodology covering all innovative activities, which takes a human as the point of reference. The discussed cognitive activity uses common sense and methods of designers to satisfy the human needs by means of technologically feasible solutions, which a reasonable business strategy can turn into a value for the customer and a market opportunity [5]. Design thinking is characterised by [5]:

- empathy—capacity to perceive reality from different perspectives—from the point of view of the co-workers, buyers, end users customers (already established and potential); focus on people when developing visions of solutions, not only desired but, above all, satisfying any hidden needs of the customer;

- analytical thinking and capacity to notice various, sometimes contradictory aspects of complex issues;
- optimism—taking up new challenges and aspirations, as well as overcoming limitations, in order to create a breakthrough solution;
- experimenting—conducting bold and daring experiments;
- cooperation—creation and operation of multidisciplinary teams.

The concept of design thinking, presented by T. Brown, in our opinion, may be reinforced and, in a way, supplemented by Altshuller's algorithm of invention [6]. The TRIZ method, developed by H.S. Altshuller, uses statistical analysis of patents (over 40 thousand) in search for innovative solution formulas. As opposed to the trial-and-error method, TRIZ allows for eliminating incorrect concepts and thus results in finding the optimal solution faster and cheaper. The essence of this invention algorithm is an action consisting of: analysis (analytical stage), elimination of technological conflicts (operational stage) and adjustment (synthetic stage). Every stage is divided into a number of subsequent activities. This way, the algorithm breaks down one general complex activity into a number of individual, simpler activities. The third mentioned element of creative thinking is strategic thinking. It is an imagination process occurring with the use of knowledge, intuition and reason, supported by relevant information about the future, enabling development of various visions and scenarios describing future and reliable conditions of functioning of the organisation, which can arise as a result of changes within the organisation itself and in its environment. The purpose of strategic thinking is [7]:

- trying to understanding the situation, examination of opportunities and threats in the environment, as well as thinking ahead;
- use of analysis methods and planning, enabling gathering of various information necessary for the needs of the innovation strategy;
- the intention to change the areas and methods of the organisation's functioning, according to the objectives adopted for implementation and changes in the environment;
- the ability to undertake risks and acceptance of uncertainty of actions;
- acceptance of the option to postpone the results of the innovation strategy implementation;
- demonstrating readiness to introduce new management methods, along with their socio-cultural implications;
- acceptance of the fact that the organisation operates in a multicultural environment.

The concept of creative thinking as the basis for creating disruptive innovations in organisation management, proposed by us, constitutes a synthesis of innovative, design and strategic thinking. We understand creation not as a type of inspiration or illumination, but as a result of an ordered process, converting experiences and feelings into creative works. Experiences and feelings result from creative thinking. On the other hand, creative works are developed in mental, objective, organisational

and market forms [8]. This integration of theory with practice constitutes the basis for creating disruptive technologies in an organisation.

An example of creative thinking is the ability to imagine the future needs of customers, which is inherently difficult. Own creative works related to preparing scenarios of the future or creating new markets are already insufficient. Therefore, creative work in an organisation requires maintaining constant contact with scientific institutes and laboratories, conducting world class research, thereby becoming a junction in the global innovation network.

In the book describing Apple companies, L. Kahney presents the functioning of a project team. A project team has been already working together for many years. None of the members of the task force designs individually anymore, but for each product the leading designer is determined, who does the majority of the work, and one or two supporting designers. Thanks to regular meetings (sessions), the designing process becomes a true team effort. Sessions usually last 3 h and all members of the team must be present. Every session begins with a cup of coffee. Two designers performing the roles of baristas prepare coffee for the whole group in an excellent coffee maker. The actual session begins with a casual, creative exchange of ideas; each of the present members is expected to give some suggestions. The sessions are chaired by the team leader, but he is not in a dominant position. Creative discussions of designers each time have a specific main topic.

Sometimes the meetings concern presentation of a model, another time details or appearance, or yet some other difficulty that appeared during designing. The discussion about common goals usually turns into sketching, drawing and exchanging ideas. The exchange of ideas is filled with criticism until it leads to constructive conclusions. Sketchbooks document intense discussions, which is extremely important, since they allow for easily coming back to the old ideas. At the end of the session, the leader requests all designers to copy their drawings and provide them to the leading designer of the project, whom the discussion concerned. The leader discusses the topic with the leading designer, and then the latter, along with his assistants, analyses the drawings once more, debating on how to incorporate the new ideas of the team into the design [9].

In our understanding, the actions described above are fully consistent with the process of creative thinking. It results in feelings, impressions, ideas and associations, which—combined with experiences and skills—lead to development of new and better solutions. Creative thinking means associating various elements to form new combinations.

The next stage of the concerned process is formation of mental creations. This notion is understood as an idea, concept, vision, plan, model or patterns common for the project team participants. In the described company—Apple, preparation of a realistic model, as faithfully as possible reflecting the shape of the final product, plays the main role when making decisions on introduction of a new and disruptive technology.

On the other hand, creative works in objective forms include: design, prototype, template and strategy. A project is an organised sequence of human activities, aiming to achieve the assumed result, contained in a finite time period with a

distinguished beginning and end. It is usually executed in a team, using a finite quantity of resources. The project may be a one-time, unique or complex undertaking. The complexity results from the number of actions that should be performed in a specific sequence in order to achieve the goals. The objective creation, defined by us as the prototype, is a device, a circuit or an application, designed and built in order to demonstrate the capacity to build the target device. During construction of the prototype, engineers for the first time put in practice their new ideas. If it is possible to build a working prototype, construction of the final device may commence.

During designing, some actual phenomena related to the construction are often ignored. In such a situation, the prototype allows for discovering their unknown effect and introducing proper adjustments. If the first prototype is successful, subsequent ones are built, until a device meeting the assumptions is obtained. The template design is equally as important. According to Jobs [10]: "In most people's vocabularies, design means veneer. But to me, nothing could be further from the meaning of design. Design is the fundamental soul of a man-made creation that ends up expressing itself in successive outer layers."

The distinguished and named by us organisational creations are results of combining and transforming mental creations and objective creations. The material used in this process consists of task forces and functional groups that, on the basis of adopted management methods and the available knowledge and competences, arrange activities preparing organisational creations for the needs of the market. In order to present this process more clearly, we can illustrate it with the following example. According to the designers' idea, several prototypes were prepared in the creative workshop (in the design studio), which underwent an evaluation process, as a result of which one of them was selected for manufacturing. Meanwhile, the task force was ordered to prepare a prototype for production.

The next phase includes introducing the prototype to repetitive (serial) production, which is entrusted to a specialised functional group (e.g. production department). On the contrary, another functional group (e.g. legal and organisational department) is tasked with preparing an offer and the conditions for introducing the organisational creation specified in such a way to the market. The final phase of the process of creative activity of an organisation is the commercialisation of the organisational creation, which may take place in one of three market forms: sale of the creative work, granting the license for the creative work and contribution of the creative work as contribution-in-kind to a newly established organisation.

3 Conclusions

The construct of creative thinking in management of disruptive technologies, proposed in the article, should be perceived in terms of broadly understood organisational creativity. This creativity is characterised not only by expression and freedom, which results from the need to try, experiment, from curiosity and desire

to independently experience the surrounding reality. It is also orderly, systematic and flexibly responds to signals coming from the environment (market, customers). This way, new and real problems are created, as well as new and more precise methods of solving them. Disruptive technologies are created accidentally or routinely. They are a result of an orderly thinking process in an organisation, which we call creative thinking.

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Relations Between IT and Organizational Learning Capability—Empirical Studies Among Polish Organizations

Katarzyna Tworek and Anna Zgrzywa-Ziemak

Abstract The aim of this article is to demonstrate the relation between the use of information technology (IT) and development of organizational learning capability (OLC) with regard to the intermediate role of organic structural solutions. The importance of an information system for the OLC is discussed and empirically verified (CFA was used on a sample of 212 companies). It enabled reflection on the relation between IT and OLC. In the light of previous studies a direct relation between OLC and the use of IT in organizations is neither obvious nor clear. This articles describes studies indicating that IT can have an indirect impact on the OLC through organic structural solutions. Using the OLC model, the role of organic structure in shaping the OLC is proven. Empirical research are presented, showing IT as a factor contributing to the organic structural solutions (the regression analysis was used on a sample of 105 companies).

Keywords Organizational learning capability · Information technology · Information system · Organizational structure

1 Introduction

Organizational learning, learning faster and more efficient than the competition, is a prerequisite for survival and development of organizations [24]. Empirical studies carried out in different types of organizations operating in different industries, cultural contexts and a number of other situational conditions, demonstrate the positive impact of organizations' learning on organizational performance and innovativeness [12]. In the article, we focus on the problem of developing the

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organizational learning capability (OLC), particularly the impact of IT on OLC is considered.

It is hard to find in the literature the concept of organizational learning that does not underline the importance of an information system for learning companies. Of course, this issue is widely explored by researchers canalyzing OLC from a technical perspective, according to which the processes of learning is simply a process of information processing [10, 14]. In turn, in the work of supporters of the social perspective, focusing on the way in which people give meaning to their own experiences at work, the importance of social communication is underlined [2, 15]. Empirical studies clearly show that appropriate information system is one of the key factors shaping the learning ability of companies [31].

In today's world the increase of importance of IT can be seen, practically in all kinds of organizations. Direct relations between IT and OLC aren't consider a certainty [8, 16]. Some authors conclude that IT have the potential to both enable and disable OLC [8, 16]. However, because of lack of reliable evidence of significant, direct relation between OLC and IT in current studies, this article is aimed at linking IT influence on OLC through some intermediate factor, keeping in mind that the actual use of IT is important—not only its availability in the company [16]. Organizational structure is identified in this article as this factor, since IT is considered by many authors as the main source and carrier of change in organizational structure [30]. Therefore, it is worth to consider not only a direct relation between IT and OLC, but also the role of IT in reorganizing to more organic structure—which is one of the important factors affecting organization learning capability.

2 IS as a Factor Enhancing OLC

In this article the OLC model by Zgrzywa-Ziemak [31] was adopted. OLC is defined as "the readiness of the organization to change its knowledge", where change of knowledge is perceived in the context of two parallel processes—the verification of the existing knowledge and the development of the new one [31, p. 34]. OLC refers to the potential of organizations to learn, and not to the course of specific processes of organizational learning. OLC is not a directly observable phenomenon, but it can be diagnosed and evaluated by the factors shaping it, and improved through these factors.

The research of Zgrzywa-Ziemak [31] proves, that the information system is one of the key factors determining the organizational learning capability. The main aim of the study was the identification of factors structure of the organizational learning capability. Determining factors were theoretically identified, defined and hypothesis about the structure of each factor and the structure of organizational learning capability were advanced. The theoretical model was empirically verified on a sample of 212 different (due to the industry, the size and form of ownership) organizations. Model verification was performed using the Confirmatory Factor Analysis (SPSS AMOS was used), generalized least squares method of estimation

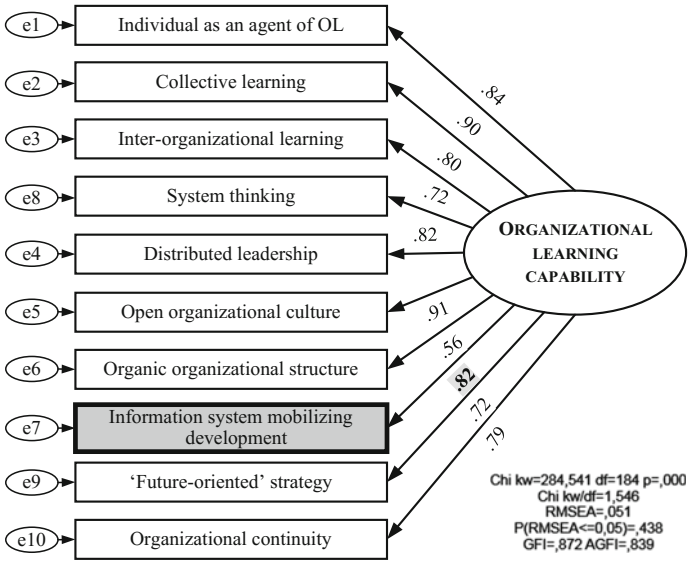

Fig. 1 Simplified OLC model (n = 212) (*Source* own work based on [31])

was used. Figure 1 includes a simplified schema of OLC model,[1] and Tables 1 and 2 present chosen estimates of OCL model.

The theoretical structure of the phenomenon was predominantly empirically confirmed. According to the measures of adjustment of the model to the data, it must be considered acceptable in view of three criteria ($\chi 2$/ss, RMSEA and P (RMSEA < 0.05)). Goodness of fit indices: GFI = 0.864 and AGFI = 0.831 do not exceed the recommended minimum of 0.9, however, such a situation can occur when the model is very complex (it's a "punishment" for increasing the number of model parameters).

According to model, the OLC is the higher, the more the information system mobilizes development. Variable 'Information system mobilizes development', which is a part of OLC model, consists of 11 items (α Cronbacha coefficient is 0.88). In particular, the higher is the OLC:

- the more intense and more casual is the flow of information within the organization and between the organization and its environment;
- the more varied are the ways of transmitting information, the more intense the parallel use of different ways, and the smaller the standardization of methods and forms of communication messages;

[1]In this article we provided a simplified scheme model of the OLC, the whole model is much more complex and has been presented in the works: [29, 31]. All loadings of estimated factors and measures of model fit refer to the original version of the model.

Table 1 Estimates of OCL model: regression weights

OLC factor			Estim.	S.E.	C.R.	P
Individual as agent of OL	←	OLC	1.000			
Collective learning	←	OLC	1.526	0.346	4.406	***
Inter-organizational learning	←	OLC	0.880	0.200	4.405	***
Distributed leadership	←	OLC	4.797	0.929	5.166	***
Open organizational culture	←	OLC	1.010	0.195	5.168	***
Organic organizational structure	←	OLC	0.250	0.063	3.960	***
Information system mobilizing development	←	OLC	3.955	0.711	5.564	***
System thinking	←	OLC	1.408	0.294	4.786	***
'Future-oriented' strategy	←	OLC	1.892	0.402	4.702	***
Organizational continuity	←	OLC	0.412	0.084	4.928	***

Table 2 Estimates of OCL model: squared multiple correlations

OLC factor	Estimate
Individual as agent of OL	0.699
Collective learning	0.811
Inter-organizational learning	0.635
Distributed leadership	0.665
Open organizational culture	0.834
Organic organizational structure	0.310
Information system mobilizing development	0.679
System thinking	0.512
'Future-oriented' strategy	0.511
Organizational continuity	0.625

- the more formal information systems are mobilizing for action (which may be implemented, inter alia through feedback systems, early warning systems and reporting focused on the development goals).

The contribution of 'the information system mobilizing development' in determining the OLC is quite high as standardized regression weight is 0.82 (Fig. 1), and the percentage of the explained variance is 0.679 (Table 2). It is a statistically significant factor in the structure of the OLC (Table 1).

3 Ambiguous Relationship Between IT and OLC

The possibility of using IT to support OLC is neither the subject of more detailed analysis, nor even seen clearly [3]. Even considering the above results (due to its limitations), it is still not quite sure that there is a direct relation between IT and OLC.

At the turn of the century, there was a range of opinions about the limitations of IT impact on OLC capabilities [4, 26]. However, even then some authors, for example Argyris and Schön [1], emphasized that IT should be seen as an essential part of a more general problem of organizational learning. Since then, more empirical research became available on this subject, indicating that the positive impact of IT on OLC is possible, but at the same time proving that it depends on some contextual factors—organizational culture [3], environment [8, 16], knowledge management [22]. The nature of these factors is not clear and there isn't any reliable studies clearly stating which factors are intermediately enabling IT influence on OLC.

While considering all the above research in order to identify what should be analyzed next, it is important to underline what many authors emphasize—that the effects of IT-enabled organizational learning mechanisms are significantly influenced by the individuals who use them [16, 22]. That means that further research should be focused on ensuring that IT is actually used by employees of analyzed organizations, not only available for them to use.

4 Indirect IT Influence on OLC

In this article organic organizational structure is considered as the intermediate factor enabling IT influence on OLC. Literature studies that lead to identifying this factor are presented and its actual effect is later verified using correlation and regression analysis.

4.1 Organic Organizational Structures Supporting OLC

Fiol and Lyles [9] argue that the organizational structure allows both innovation and new insights, so it is an essential contextual factor that affects the probability that learning will occur at all. Stinchcombe sees organizational structure as a kind of basis for organizational learning, which designs ways of acquiring information about the world, and improving what the organization is able to do (Stinchcombe 1990 cit. after [21]). According to Sakalas and Venskus "the concept of quickly changing, learning organization is impossible to realize without respective organization management structures" [23, p. 69]. Dodgson defines a learning organization as the one which deliberately adopts such structures and strategies to stimulate learning [7]. According to Martínez-León and Martínez-García the organizational learning capability is influenced by structures because the organizational structure influences the information flows and it plays a fundamental role in a company's capacity to identify the knowledge sources needed, acquiring new knowledge, integrating it into the organization and recognizing its absorptive capacity [18].

Several authors over the years tried to overcome this challenge with different structural ideas. Nonaka and Takeuchi hypertext structure is probably the most known one—as the most advantageous for permanent and effective organizational knowledge creation [20]. But there are also modular structure forms [11], project structure forms [6], network structures [18] or 'new economy structures' [17]. But all these ideas have one thing in common—the authors propose organizational structures that are more flexible, flat and adaptive. Proposed solutions usually facilitate departure from the principle of hierarchy, question the classical principle of unity of command and Taylor's division of employees to the conceptual and executive ones. These rules are eliminated for the benefit of control and coordination within the horizontal complex relationships between individuals and cooperative relations. Hierarchy of tasks, determined by their range is more important than hierarchy of organizational power. There is a decentralization of decision-making authority, individuals and organizational units have considerable autonomy. There is also a disappearance of functional specialization in favor of a specialization of objective nature, focused on the implementation of a specific tasks.

Therefore, it seems that behind different names and proposals presented by each author—the general idea is the same. Structures facilitating OLC in organizations should me as organic as it is possible (the typology proposed by Burns and Stalker's (1961) containing 'mechanistic' and 'organic' organizations is used here). Since there isn't many reliable papers available on that topic, it seems to be interesting to explore what factors can influence organizational structure, facilitating its reorganization to more organic-type one—better suited for organizations wanting to enhance their learning capability.

According to model, the OLC is the higher, the more structural solutions are moving towards organic solutions (on a continuum from a mechanistic model to the organic model). In particular, the higher is the OLC, the lower the degree of standardization and formalization, the more horizontal interactions dominate in the communication, coordination, and control, the more the hierarchy of objectives dominates over the hierarchy of positions. The study has shown that the degree of specialization and centralization is not relevant for the studied phenomenon. Although contribution of the organizational structure in determining of the OLC is the lowest relative to other factors, since standardized regression weight is 0.56 (Fig. 1), and the percentage of the explained variance is 0.310 (Table 2), it is a statistically significant factor in the structure of the OLC (Table 1). Subsequent studies on the relationship between organizational structure and the learning of the organization, though quite limited, confirm the nature of organic structural solutions for organizational learning (including centralization and specialization dimension): complexity [13, 19, 31] standardization [19, 31] formalization [18, 19, 25] specialization [18, 19, 25, 31] and centralization [13, 18, 19, 25]. The studies have been conducted in different cultural contexts (mainly in Europe and Asia), in organizations different in terms of industry, size and ownership, profit oriented and non-profit.

Therefore, it is worth to look at the organizational structure in the context of OLC and define what are the factors that may influence its reorganization into more organic-type one. Theory describing factors that influence organizational structure

is very complex. Most authors lists at least several structure-building factors. The most common, obtained from Leavitt's organizational model, are: strategy, employees, technology, environment. Taking into account the fact that nowadays it is common knowledge that organizational structures are reorganizing into more organic-type ones, the authors concentrated on factors known to influence organizational structure shift in that way. This article is focusing on IT as a factor that may influence organizational structure.

4.2 IT Acceptance

Information technologies (IT) are defined as application of computers and telecommunications equipment to store, retrieve, transmit and manipulate data. Since the '70s of the last century, researchers were convinced that there are a number of factors which influence whether the technology will be adopted in the organization or not. In the '80s, they directed their efforts towards creating a method that would allow to predict the dissemination of technology in the organization. In the context of IT, dissemination will be understood as the extent in which they are applied in the organization. The accessibility of information technology in the organization is understood as the number of members of the organization having access to these technologies. It is worth noting here that the count is the number of unique visitors—individuals with access to IT. Thus, regardless of what the frequency of technology use is (if they do not use it at all, use once a month or several times a day), each user is counted once and only once. Therefore, it consider members who have access to IT, but not necessarily use it. The next step was to develop methods that allow to specify how many users actually use IT in their work. That was the genesis of the concepts of IT acceptance. It has allowed to take into consideration the imbalance between the number of users who have access to IT and the number of users actually using it. IT acceptance, understood as a demonstrable willingness within a user group to employ IT for the tasks it is designed to support [5], will be a variable used in this publication to characterize IT in organizations.

5 IT Influence on Organizational Structure

Relations between IT and organizational structure were tested as a part of studies, conducted in 2012 (as a part of Ph.D. Thesis [27]). 105 organizations were examined (they were different in terms of size, industry and ownership structure). All of these organization have implemented IT systems (they were different in terms of dissemination, user acceptance and type—construed as number and nature of implemented IT function) and claimed that IT is used, among others, to support organization learning.

To investigate the results of the relation between IT and organizational structure, the key variables describing 4 organizational structure dimensions were defined: hierarchy, centralization, formalization, specialization. Subjective level of each variable was calculated as the arithmetic mean of grades given to each item describing one of 4 variables. Items were put in form of statements and they were rated by the respondents with Likert scale (5 items scale) and are concerning level of hierarchy complication, place of variety of decision-making, number of regulations and nature of typical tasks (all items are available in [28]) It is worth noting that Cronbach's α was 0.641 and higher for every variable, which indicates a high internal reliability of the scales and measurements.

IT was described by degree of IT acceptance in organization. Subjective level of IT acceptance was calculated based on a set of statements prepared on basis of IT acceptance measuring method proposed by Davis—set of statements and detailed information were published by Martan and Tworek [28]. Additionally, Cronbach's α was calculated for this scale—it came back as 0.905 which indicates very high internal reliability of scale.

Firstly, correlation analysis using Pearson Coefficient was done. Analysis has indicated that there is indeed the correlation between IT acceptance and hierarchy complexity, degree of centralization, formalization and specialization, which may indicate that with increase of IT acceptance, the organizational structure changes into more organic-type one (hierarchy is less complex and centralization, formalization and specialization degree is smaller).

Secondly, stepwise regression analysis was performed. Fitting models were obtained for hierarchy ($F\ (4.99) = 14.585$, $p < 0.001$), formalization ($F\ (3.100) = 8.357$, $p < 0.001$) and specialization ($F\ (4.99) = 23.145$, $p < 0.001$). IT acceptance proved to be a significant independent variable with every obtained model (Table 3). IT acceptance proved to be the only significant independent variable in Model obtained for centralization ($F\ (1.102) = 9.690$, $p < 0.05$). This model cannot be characterized as fitting—obtained predictors explained only 7.8 % of the variance of the dependent variable.

Table 3 Regression analysis between organizational structure and IT acceptance

Independent variable in regression models		Dependent variable in regression model			
		1st model: hierarchy	2nd model: centralization	3rd model: formalization	4th model: specialization
Information technology acceptance	B	−1.133	−0.489	−0.481	−0.426
	Standardized error	0.193	0.150	0.201	0.129
	Beta	−0.538	−0.356	−0.248	0.277
	T-student test	−5.884	−3.262	−2.396	−3.303
	Significance	0.001	0.002	0.019	0.001
	Significant element of regression model	Yes	Yes	Yes	Yes

Regression analysis has shown that with increase of IT acceptance there is a significant change in each variable characterizing organizational structure. Hierarchy complexity declines, as do the degree of centralization, formalization and specialization. It confirms that organizational structure becomes more organic-type one.

6 Conclusions

Information system is one of the key factors influencing OLC, however there aren't any reliable studies analyzing relations between IT and OLC—both direct and indirect. Authors identified IT as a factor which may contribute to structure reorganization and proposed a study that was conducted in order to analyze the relation between IT and OLC.

It is important to underline that the empirical studies confirm theoretical views that the learning of contemporary organizations is promoted by organic structural solutions in all dimensions (complexity, standardization, formalization, specialization and centralization). OLC development, however, requires the selection of such instruments of shaping the organic structural solutions that will increase the freedom of action of organizational members by increasing access to information and knowledge, promoting the transfer of information and knowledge, supporting the development of new knowledge and using it in action. Conducted research has shown that IT indeed impacts organizational structure and contributes to reorganizing to structure less complex, with lower degree of centralization, formalization and specialization.

It can be concluded that the research provides evidence that in fact there is an increase of self-reliance among employees using IT, which contributes to the increase of the average span of management and results as lower centralization level and less complex structural hierarchy in organizations with highest IT acceptance. However, centralization, which is getting lower with increasing IT acceptance can be primarily the evidence of incensement of information synergy on the lower levels of management—the effect most desired in organizations trying to enhance their learning capability. This increasing of IT acceptance leads to the situation, in which employees are in fact better equipped to make the right decisions in place, in which the problem arises and results with lower degree of centralization.

It is also important to underline that conducted research supports Kane and Alavi [16] view suggesting that IT may influence the OLC only because of individuals who are using it. Utilization of IT acceptance as a variable characterizing IT and confirming its significance for reorganization to more organic-type structure gives empirical confirmation of that. Because of that variable choice, authors of this article were able to analyze IT ensuring that it is used by employees of analyzed organizations—not only is available for them.

It can be concluded that increasing IT acceptance can in fact contribute to reorganizing structure into more organic-type one, thus indirectly IT promotes the development of OLC.

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Efficiency and Maturity Assessment Model of RUP Process in IT Organizations

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Abstract A crucial problem in modern software engineering is maturity assessment of organizations developing software, however, research has shown that efficiency is a clearer indicator of agile transformation readiness. We propose utilizing a process model of RUP development methodology, as a pattern for comparing it with the examined process. Two factors were proposed to assess maturity and factor determining the efficiency of the RUP process. The above mentioned RUP model concept is based on a multi-agent based simulation (MABS). It presents goals and behaviours of agents as well as components of the agent system environment. To confirm the usefulness of the method for assessment of organization's maturity, a two-fold experiment was undertaken. The results confirm the usefulness of the model in efficiency and maturity assessment. First part consisted of tuning the simulation internal parameters to the development process. In the second part we propose three factors that can be used to assess efficiency and maturity of a RUP IT organization. The proposed coefficients are an extension of previous research by the authors, devoted to the assessment of organizational readiness for agile processes transformation.

Keywords IT organization maturity · Software development processes · Rational unified process · Maturity assessment · Efficiency assessment · Software process simulation · Multi-agent · MABS · JADE · AGOMO

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1 Introduction

In recent years we have seen a rise in interest regarding transformation problems of IT organizations from the traditional Rational Unified Processes RUP [1], to agile methodologies, such as SCRUM [6], XP [1]. Interest in the processes of transformation is the result of a large number of failed projects implemented by these organizations. Hence, IT organizations are looking for solutions to ensure the effectiveness of agile transformation. Conducted research of transformation processes is focused on the analysis of transformation paths, (technology, process, design and organizational culture) and the methods used to determine an organization's readiness for starting the process of agile transformation [3–5]. In the latter case, it is assumed that the achievement of the organization's particular state of readiness is a necessary condition for the start of the transformation process. Analysis of the state of preparedness is the challenge for the authors of this article.

This analysis considers the relationship between the efficiency and maturity of the development processes and its impact on the readiness state of organizations for agile transformation. The use of an agent-object system is proposed for analysis of an example RUP development methodology. RUP describes both development and management processes, as well as determines their efficiency and the utilization in the various phases and iterations of the development process. Process roles are defined as well. Hence, RUP is an excellent example for the description of the development process, as well as a formal description, which can be the basis for its simulation using agent systems.

This integration of RUP and the agent system formed the basis for construction of the AGent-Object MOdel (AGOMO) system simulating the workflow of the development team. In the first phase, it was assumed that the research system will be used by project managers to predict scheduling of software development projects. It turned out, however, that in the course of work on the issues of transformation of IT organizations, from the point of view of managers of those IT organizations, examining the state of readiness utilizing the agent-object system is more valuable. Therefore, the authors have proposed to treat the forecasts of the AGOMO as a measure of organizational readiness for the processes of agile transformation.

This article is the next one on the assessment of readiness for agile transformation based on the AGOMO system. The compliance rate of RUP process flow model pro-posed in the first article proved insufficient. Therefore two factors determining the efficiency and compatibility of the roles of the process tested were added.

Because of that, the article is divided into three main parts. In Chap. 2 we presented an agent-object model of the RUP process. In Chap. 3 we present the experiment confirming the usefulness of this method. In Chap. 4 we summarize the results of the experiment and draw conclusions.

2 AGOMO. Agent-Object RUP Process Model

For the analysis of the project and its development processes, compatible with the RUP model, it is proposed to use the agent-object system.

The developed system is based on the model of design environment, which consists of:

- project plan model (based on RUP standards),
- artefact repository,
- development team model.

At the outset, the model was built, and was subjected to the process of implementation using the Jade environment. The simulation model has been designed as a multi-agent system [7]. Members of the project team are mapped as agents performing the tasks assigned to them, in corresponding project roles, according to the project plan and activities flow.

The task involves processing the input artefacts located in the repository into output artefacts and saving them to the repository. Figure 1 shows the agent-object system model.

Inside the model, dynamic components are represented by the agents placed in an agent environment, containing passive objects to which agents have access and which perform operations that comprise the mapping of the software development process.

Agents can be approximated as a stand-alone computer programs, operating independently of each other, having the ability to communicate among themselves,

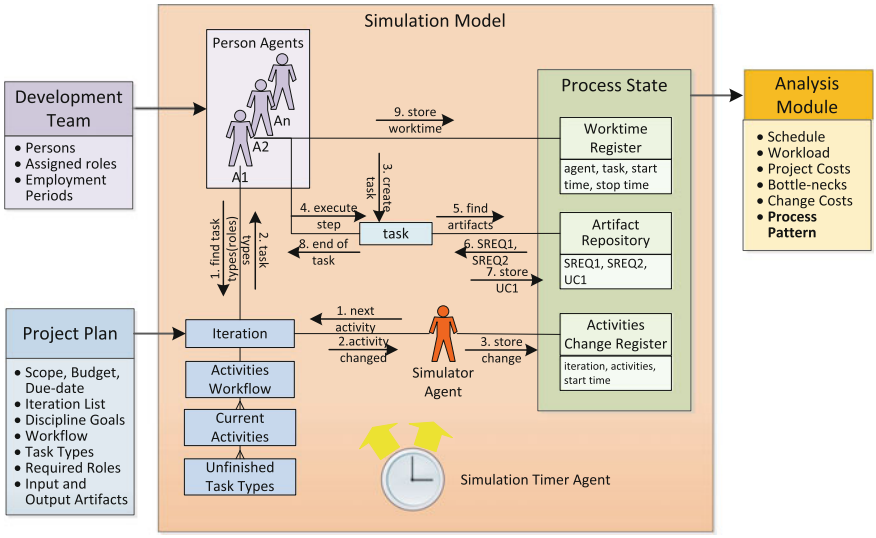

Fig. 1 The agent-object system model for project status analysis of the RUP process

observing the environment in which they are located, as well as decision-making, and having an impact on the environment. Classes of objects and agents in the system simulation:

Project Plan Object. This is the model input data. Project plan model is understood as a set of iterations I_i performed during the project:

$$PP = \{I_i | i = 1 \ldots n\} \tag{1}$$

According to RUP terminology, iteration I_i consist of activities $O_{i,k}$ defined as subsets of elementary tasks E:

$$I_i = \{O_{i,k} | k = 1 \ldots m\} \tag{2}$$

where: $O_{i,k} \subset E$

Elementary task set E contains base (indivisible) operations which can be implemented in a given development environment, i.e. Find Actors And Use Cases. Task $e_l \in E$ is described by a sequence: $e_l = (r_l, ai_l, ao_l, d_l)$ defining the role of an agent (r_l), which can accomplish the task, a collection of input artefacts required to start the task ($ai_l \subseteq A$) a collection of artefacts obtained after the completion of the task ($ao_l \subseteq A$), the duration of the task (d_l—measured in units of agreed time, u.a.t.).

Development Team Object. This is the model's input. Members p_i of the development team T are described by the set of assigned roles $r_{i,k}$

$$T = \{p_i | i = 1 \ldots m\} \tag{3}$$

$$p_i = \{r_{i,k} | k = 1 \ldots s\} \tag{4}$$

Based on information about the members of the project team Agent Simulator creates the agents representing team m.s.

Artefact Repository Object. It a part of the process state. The repository is responsible for storing instance of artefacts by type, assigning artefacts unique identifiers, creating specified type of an artefact instance, and search for instances of artefacts according to the specified type.

In the model, the ability to carry out the elementary tasks e_l depends on access to the required artefacts ai_l. The types and number of available artefacts in the system simulation is determined as a pair defined in the repository:

$$R = (A, \varphi) \tag{5}$$

where: A—is a collection of design environment artefacts, $\varphi(a, t) = \varphi_{a,t}$—function specifying the number of type a artefacts $a \in A$ at a discrete point in time t

Worktime Register Object. It is a part of the process state. The register stores information about which type of a task was performed by the agent, as well as when it began the task and when it finished.

Activity Change Register Object. This is the model output and an element of model state. The register stores information about the changes in the flow of the project. Information about the active iteration of the project, current activities, and simulation time at which the change occured are stored.

Person Agents. Project team del is a collection of person agents. Each agent represents p_i—a member of the actual development team T.

$$G = \{g_i | i = 1 \ldots p\} \tag{6}$$

where the agent is characterized by the following sequence:

$$g_i = \left(p_i, \{b_{i,k} | k = 1 \ldots r\}\right) \tag{7}$$

which defines the member of project team p_i., as well as its behaviour $b_{i,k}$. set.

Person agent behaviours are supporting:

- searching for types of tasks to be performed, that are appropriate to their assigned roles in the project
- creating and executing tasks based on the searched type of task
- saving information about theory done in the Worktime Register
- cooperation with other agents for joint execution of tasks

Simulator Agent. Controls the execution of the project plan. It is responsible for:

- initializing of the agent environment and the creation of agents
- switching of activities and citations in the project plan
- storing information about changes to current activities and iterations in Activity Change Register
- ending the simulation, the removal of agents, and storing the course and final state of the simulation

Implementation details of the simulation clock agent have been presented in [8].

In the context of the above definitions, simulation system SS. can be represented as a sequence containing the project P defined on the set of elementary tasks E, artefact repository R and agent set G:

$$SS = (PP, E, R, G) \tag{8}$$

Behaviour of the simulation system is a set of tasks performed during the project simulation:

$$S = \{W_i^S | i = 1 \ldots n\} \tag{9}$$

$$W_i^S = \{O_{i,k} | k = 1 \ldots m\} \tag{10}$$

where: W_i^S—i-th task of simulation S, $O_{i,k} \subset E$.

The simulation is related to the schedule for completion of elementary tasks:

$$X^s = \left\{x_{i,j,k} | i = 1 \ldots n,\ j = 1 \ldots m, k = 1 \ldots z\right\} \tag{11}$$

where: $x_{i,j,k}$—and start time of the i-th task, in regard to activity j-th and elementary task k-th

Based on the schedule of elementary tasks, a schedule of activities can be defined, which is used as a process pattern to examine the accordance of the actual design process with the RUP model:

$$\overline{X^S} = \{x_{i,j} | i = 1 \ldots n,\ \ j = 1 \ldots m\} \tag{12}$$

where: $x_{i,j} = min\left\{x_{i,j,1} \ldots x_{i,j,z}\right\}$.

3 Application of the AGOMO System to an Actual RUP Project

The aim of the experiment was to use the agent-object system to assess the maturity of the actual development process that is in accordance with RUP.

Proposed in the previous article [8] compliance rate of the process tested with the standard RUP process proved insufficient, because the test process can be inconsistent with the pattern, but conducted in a smooth and efficient manner. Indicators to assess the process are extended to the efficiency index and the rate of compliance for tasks with roles in design. Efficiency indicator is calculated on the basis of internal parameters of the simulation and therefore its value does not depend on the size of the project, the size of the project team and modifications in the RUP process.

The experiment consisted of two phases. The first stage was planned to measure the size of the project, preparation of information about completed tasks and tuning parameters of the internal model to the actual process.

Second stage was planned to use the fine-tuned simulation as a pattern to assess the maturity of the development process in the tested process.

The input for the experiment was detailed data on the course of the development process of a large information system in the field of insurance. The system was created as an extension of a previous version, with significant changes in architecture and functionality. The development process lasted for 5 years, the project team employed to design consisted of 30–210 people. The number of tasks performed during the development of the system was over 24,000. The duration of the project simulation was about 45 min.

Table 1 Results of the first part of the experiment

Output variable	Actual value	Simulation result	Relative error (%)
Number of artefacts	15517	14945	3,70
Effort of project in man-hours	319130	308703	3,30

3.1 The First Stage of the Experiment Using the Agent-Object Model to Assess RUP Process Maturity

The aim of the first stage is to obtain a process pattern matching the RUP process. To do this, size of the project was estimated and internal parameters of the simulation were adjusted.

Estimating the size of the project using the UCP method has been presented in [8].

Tuning the number of artefacts in the model. The time to complete tasks and simulation workload depends on the number artefacts in input. Therefore, the first step was tuning simulation's internal parameters, in order to get the number of artefacts created in the simulation close to the tested project. There are results provided in Table 1

3.2 The Second Phase of the Experiment—Utilizing Agent-Object Model to Assess RUP Process Maturity and Efficiency

In the second phase of the experiment we define and calculate the value of the two factors that make up the evaluation of process maturity and efficiency coefficients of the process.

The tested project is defined as a set of task performed during the project:

$$P = \{W_i^P | i = 1 \ldots n\} \tag{13}$$

$$W_i^P = \left(p_i, \left\{O_{i,k} | k = 1 \ldots m\right\}\right) \tag{14}$$

where: W_i^P—i-th task of tested project P, is defined as a team member p_i. performing a task and activities, $O_{i,k} \subset E$, which can be part of the task.

The project is related to its schedule:

$$X^P = \left\{x_{i,k} | i = 1 \ldots n, k = 1 \ldots m\right\} \tag{15}$$

where: $x_{i,k}$—start time of i-th task, k-th activity of project P

Table 2 The results of the comparison between tested process and the process pattern

Variable	Description	Value
q_a	Number of tasks in accordance	33396
q_t	Total number of tasks	51701
A_a	Activity accordance coefficient	65 %

The accordance of the project ask with the simulated task is marked:≡ and defined as such:

$$W_i^P \equiv W_i^S \; if \; \exists \; o_i \; \in \; O_i^S, \; \text{for which } (x_{i,j}^P \geq \overline{x_{i,j}^S}) \wedge (x_{i,j}^P \leq \overline{x_{i,j}^S} + d_{i,j}^S) \tag{16}$$

where: O_i^S—activity set, $d_{i,j}^S$–time span of i-th task, with regards to j-th activity in the simulation result.

Activity accordance A_a. is defined as the percentage ratio of the number of tasks in accordance q_a. the total number of tasks q_t. Calculation results are given in Table 2.

$$A_a = 100\,\% \frac{q_a}{q_t} \tag{17}$$

The task is consistent with the roles of design, if the person performing the task is assigned at least one of the roles required by elementary tasks.

$$W_i^P \equiv T, \; if \; \exists \, e_k \; \in \; O_{i,j}^P \; \text{ where } r_k \; \in \; p_i \tag{18}$$

Role compliance of project is defined as a percentage of the number of tasks in accordance with design roles q_r to the total number of tasks q_t (Table 3).

$$A_r = 100\,\% \frac{q_r}{q_t} \tag{19}$$

Performing of elementary tasks involves processing input artefacts into output artefacts. The tasks of processing artefacts of an individual nature have a processing time linearly dependent on the number of processed artefacts defined by the formula:

Table 3 The results of the comparison between activities and team members roles

Variable	Description	Value
q_r	Number of tasks in accordance	45459
q_t	Total number of tasks	51701
A_r	Roles accordance coefficient	88 %

$$t_l = \frac{a_i a_o}{t_p} \tag{20}$$

where: a_i—internal parameter describing the number of input artefacts per one output, a_o—The internal parameter specifying the number of output artefacts produced in one processing cycle, t_p—The internal parameter specifying the duration of task processing in u.a.t.

The tasks of processing group artefacts have time processing non-linearly de-pendent on the size of the project and defined by the formula:

$$t_n = 1 + t_p\left(1 - e^{-\frac{S}{L}}\right) \tag{21}$$

where: S—the size of project in UCP, L—constant value of 3000, t_p—internal parameter defining internal processing time.

Internal parameters determine the model fit to the test project. Their values therefore reflect the efficiency by elementary tasks, which the process of software development consist of.

On the basis of design data stored in the database ISBSG [2] standard values of internal model were set. These values form the reference for determining the efficiency coefficient of the test project.

The efficiency coefficient P_t for an elementary task is defined as the ratio of time spent performing tasks in a reference project t_{ref} to the time in the tested project t_x. The coefficient from the range (0, 1) means that the efficiency of the project under consideration is less than the reference design. The value above 1 means greater efficiency of the design examined.

$$P_t = \frac{t_{ref}}{t_x} \tag{22}$$

The efficiency coefficient for the discipline, category or the entire project is calculated as the arithmetic average of the weighted component efficiency P_i and effort E_i of elementary tasks. The calculated value is in Table 4.

$$P = \frac{\sum_{i=1}^{n} \frac{E_i}{P_i}}{\sum_{i=1}^{n} E_i} \tag{23}$$

Table 4 The efficiency measurement result in relation to the reference project

Variable	Description	Value
P	Project efficiency coefficient	0.22

4 Conclusions and Future Work

The aim of the research was to use the agent-object system developed by the authors to analyse the RUP process in an IT organization. It was assumed, that the use of the system will show the maturity of an IT organization using RUP, for the eventual transformation process, based on the internal parameters of the simulation. The article presents the design of the model, showing its verification environment, as well as the use of the system in the in implementation of an actual IT project. The research experiment, the aim of which was verification of the developed model consisted of two phases. Preliminary, under which the system was used for fine-tuning, and the second, which was used as a pattern for comparison with the course of the test project.

The results in the first phase of the experiment showed that the parameters of the project: the size of the project measured by the UCP method, workload of the project activities, the number of artefacts and workload by category of tasks, has created conditions to tune the system so that the relative error was small.

The results of the experiment in the second phase indicated that the development processes ended earlier than the actual ones analysed. Therefore, there is a large discrepancy in activities at the end of the development process.

The proposed factor of efficiency can have a greater importance for the assessment of readiness to agile transformation than process maturity. This is due to the fact that completion of the project within an allotted period is of more practical importance than compliance with the standard RUP process. Poor efficiency at high rates of compliance in activities and roles may indicate the inadequacy of the RUP process application to the project.

In the article it was found that the efficiency of the project under consideration is about 4.5 times lower than in the reference project, the compatibility factor activity is only 65 %, which indicates low maturity RUP processes in the organization. Compliance of tasks with roles in design at the level of 88 % means that the project team members doing the work for the most part in accordance within their competence.

It is proposed that further work on the use of AGOMO to determine the maturity of processes RUP the organization will concern the aggregation of three proposed coefficients to one of a standard scalar 1–5.

Therefore, in view of further assessment studies of an organization's readiness for agile processes of transformation, it must be considered how parameters typical for a mature organization's performance may provide a basis for classifying it in assessing the readiness of the organization.

The results obtained in the first and second phase of the experiment indicate on one hand, the ability to forecast the state of the project using the tuning of the agent-object system parameters, yielding a small relative forecast error, but on the other do not create the conditions for accurate assessments of RUP processes.

This may mean that since the organization is not able to predict the state of its processes so its maturity is low in synthetic terms.

This does not mean, however, that if the organization is not mature, the risk of agile transformation is high. Such research was not conducted by the authors.

They assumed that the maturity analysis for the start of agile transformation should be carried out before the management decides to implement an such a transformation.

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Application of Neural Network to Predict Purchases in Online Store

Grażyna Suchacka and Sławomir Stemplewski

Abstract A key ability of competitive online stores is effective prediction of customers' purchase intentions as it makes it possible to apply personalized service strategy to convert visitors into buyers and increase sales conversion rates. Data mining and artificial intelligence techniques have proven to be successful in classification and prediction tasks in complex real-time systems, like e-commerce sites. In this paper we proposed a back-propagation neural network model aiming at predicting purchases in active user sessions in a Web store. The neural network training and evaluation was performed using a set of user sessions reconstructed from server log data. The proposed neural network was able to achieve a very high prediction accuracy of 99.6 % and recall of 87.8 %.

Keywords Artificial intelligence · Neural network · Web mining · Web usage mining · E-commerce · Online store · Web store · Log file analysis

1 Introduction

The immense popularity of online stores and the vastness of products they offer has motivated development of efficient search engines, recommender systems, and price comparison services on the Internet. On the other hand, competitive Web stores have to be able to provide e-customers with personalized service. In the situation where there are only a few seconds to attract customer's attention and other online stores are just a click away, it is crucial for online retailers to anticipate customers' needs and identify potential or future buyers.

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We propose application of an artificial neural network (ANN) to predict purchases in active user sessions on an e-commerce site. The rationale for our approach is that behavior of users who decide to buy products in a Web store differs from behavior of users who confine themselves to browsing the store's offer [1]. ANNs are known for very good generalization capabilities and they have been successfully applied as a prediction model in multiple areas. Their great advantage is that no prior assumptions or knowledge on data relationships is needed—only a training set of input-output examples is required, which is especially significant in real-time complex systems, like online stores.

The structure of our paper is the following. Section 2 overviews related work on application of neural networks to the Web and electronic commerce. Section 3 provides a brief background on artificial neural networks. Section 4 discusses our research methodology, including the way of reconstruction and description of user sessions in a Web store and the proposed ANN model. Section 5 explains the process of network training and evaluation in detail and discusses the network efficiency. Section 6 concludes the paper.

2 Related Work

Artificial neural networks have shown their strength in classification and prediction tasks on the Web. ANN models have been incorporated in multiple mechanisms aiming at improving Quality of Service (QoS) and Quality of Experience (QoE or QoX).

One of popular ANN application areas has been Web page prefetching (link prefetching). With the ability to predict the next page in a user click-stream Web servers may improve the user's access to server resources. Internet browsers may pre-load Web resources to speed up loading of the pages. An example of such an approach is discussed in [2] which presents an intelligent Self-Organizing Map (SOM) based approach to perform Web usage mining and predict the next downloaded page based on previously visited pages. The predicted page may be cached at the server before the user's demand which greatly improves the Web access.

ANNs have been very successful in delay prediction, both in the Internet and on Web servers. Modeling and prediction of the Internet end-to-end delay using recurrent neural networks (RNN) was proposed in [3]. Delays between two Internet nodes were measured as Round-Trip Times (RTTs) during several days. RTT historical data provides a time series which is used as the network input whereas RTT forecast is the output. In [4] an agent-based mechanism for predicting the service response time in a server cluster was proposed. The predictor agent uses Non Linear Auto Regressive with External Input (NARX) time series forecasting technique based on neural networks. Predictions on future values of response time of a Web service are made using information on the past values of arrival time and response time.

In [5] an approach to request distribution in a cluster-based Web system using neuro-fuzzy models of Web servers was presented. Local Fuzzy-Neural Adaptive Request Distribution (LFNRD) algorithm is used by a Web switch responsible for determining a server that will process each HTTP request. A neural network model makes it possible to assess service time at each server in the cluster so that the request could be sent to the least loaded one. The similar neuro-fuzzy model was developed to improve request service times in a globally distributed cluster-based Web system [6].

Many studies explored ANN-based models to discover user navigation patterns on e-commerce sites and to forecast customer behavior, e.g. for product recommendation purposes. In [7] neural networks were applied to predict users' intention of buying, seeking, and abandoning. The authors proposed a data mining approach to assess user's knowledge and needs for specific products. The sequence mining technique was used to discover users' navigation patterns. Based on the discovered patterns an ANN was constructed to predict potential customers' needs in the future. The approach may be used in a personalized recommendation system in a Web store.

The problem of generating personalized recommendations on an e-commerce site was addressed in [8]. The approach uses a Kohonen neural network and self-organizing map (SOM) off-line, to discover user group profiles based on Web log data, and on-line, to examine active user's click-stream data, assigning the user to a specific user group and recommend an appropriate set of product browsing options.

In [9] neural networks were combined with a genetic algorithm and collaborative filtering and incorporated into a framework developed for making e-commerce sites more flexible and functional. Based on the pre-processed log data, discovery and analysis of Web usage patterns is performed followed by application of the SVD (Singular Value Decomposition) algorithm on user ratings and modeling the website structure. Then a neural network is used to learn user navigation patterns and the genetic algorithm is used to improve the site usability. The proposed framework changes the structure of the online store based on two criteria: sales conversion rate and average pre-purchase page views, finally resulting in the better website usability.

Graña et al. [10] addressed the problem of trust prediction in trust-aware Web services, like online recommendation systems. Trust relationships are predicted on the basis of reputation information. The problem of two-class classification is formulated, in which feature vectors are built based on trust values about the trustee communicated by trusted users. Prediction was realized by applying the SVM classifier and two ANN approaches: the multi-layer perceptron and the radial basis function network.

Neural networks have been applied to forecast aggregated sales based on historical data. Doganis et al. [11] proposed a framework for development of time series models for daily sales forecasting. The approach uses the radial basis function neural network and a genetic algorithm. By incorporating the day-of-the-week effect and the impact of national holidays on daily sales they were able to predict sales volumes for individual days of the next year. The problem of aggregated sales forecasting was also studies in [12], where forecasts of monthly retail sales were

performed using the ANN and some traditional statistical techniques. The study showed that the neural network model outperformed other methods in terms of ability to forecast aggregated retail sales, especially for time series with strong trend and seasonal patterns.

Our study addresses the similar prediction problem for a Web store but in contrast to the above studies, our goal was to predict purchases made by individual users interacting with the site, based on their behavior during current visits. Other ANN approaches addressing this problem, e.g., [13] used detailed customer transaction data at the neural network input. High-level transaction data, like product prices, customers' age or lifetime values, makes it possible to model a user session more accurately and prediction results will be more evident. In contrast, our approach has such an advantage that it is based on user sessions reconstructed from low-level HTTP data, recorded in Web server access logs. Such data is easier to obtain from real online retailers because it does not contain sensitive information relating to company's sales and customers' personal data. Our previous research [14, 15] has shown high efficiency of data mining methods in purchase prediction based on server log data and this has motivated us to apply artificial intelligence methods to this problem.

3 Artificial Neural Networks

An artificial neural network (or simply a neural network) is a group of interconnected units (called neurons) organized into a multi-layer architecture, able to process information in the way inspired by biological neural networks. Neural networks are used to approximate functions that generally are unknown and can depend on a large number of inputs. ANN's nature is adaptive—it is capable of machine learning and pattern recognition through the training process using sample inputs [16]. A typical structure of a neural network is depicted in Fig. 1.

This model is called a multi-layer perceptron (MLP) and consists of three layers. The input layer neurons correspond to model inputs and are connected with hidden layer neurons, which are in turn connected with output layer neurons, representing the network response. Relationships between the neurons in adjacent layers are stored as weights of the connecting links.

Once the network structure has been determined, the network should be trained. At the beginning of the training process weights are initialized with random numbers. The network training consists in adjusting these weights based on the training set so that the error between the actual and the predicted output values is minimized (the desired response for each learning sample must be known so this is the case of the supervised learning). The most popular algorithm used to optimize weights in the MLP neural network is the error back-propagation learning algorithm.

Input signals are transferred from the input layer to the hidden one according to the connecting links. In the hidden layer signal values are changed through the current weights, summed and then the sum is transformed by the activation

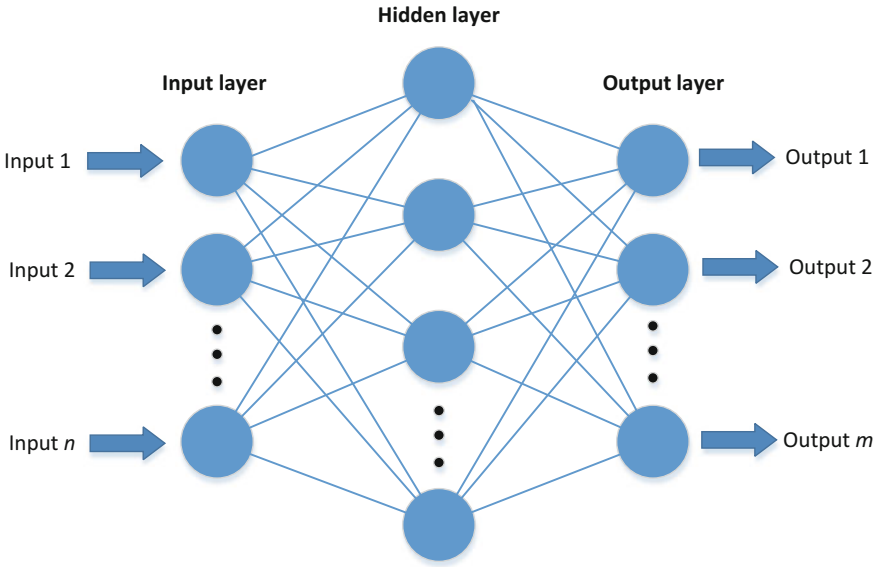

Fig. 1 A multi-layered artificial neural network

function. Similarly, the output signals of the hidden layer change according to the weights and the sum of modified signals is transformed by the activation function. The output is represented by values observed at the output neurons [7, 17].

Various activation functions may be implemented in an ANN. We used the hyperbolic tangent which gives values from the range [−1, 1]:

$$f(x) = \frac{1}{1 + e^{-\beta x}} - 1. \tag{1}$$

The accuracy of the model is determined by comparing the output of the network with the actual data. In our model the error is computed as the derivative of (1).

After each training run the weights are updated starting from the output nodes backward to the hidden nodes. A training procedure is iterative and is terminated when the actual response converges to the expected response. The stopping criterion may be, e.g., the error below or equal to a predefined acceptable error rate [18].

4 Methodology

We used data written in Web server logs from 1 April to 30 September 2014. The server hosted an online bookstore selling books, audiobooks, films, computer games, etc., together with some pages with the related contents, like quizzes, simple games, or short videos. User visits were reconstructed and described using a C++ program.

4.1 Reconstruction of User Sessions

A single user's visit to the online store is called a user session and is represented as a sequence of HTTP requests. Requests may concern page views or may be hits for objects embedded in Web pages, e.g. image files. At a high level a user session may be represented as a sequence of user clicks, connected with performing various operations typical for online stores—browsing a page with product details, adding a product to the shopping cart, etc. A key operation in session is confirmation of an order, i.e. making a purchase. Depending on whether this operation occurred in a user session or not, the session may be a buying session or a non-buying session.

Since we were interested in predicting purchases in sessions of human users, we eliminated sessions performed by Web bots and a site administrator, as well as very short sessions containing only one page view and/or lasting only one second. Furthermore, we refined a description of user sessions using additional data collected by a php-based tracking software integrated with the analyzed online store.

The set of sessions was divided into two disjoint subsets: a training set L, used to train the ANN model, and a test set T, used to evaluate the model. L and T contained both buying and non-buying sessions ($L = L_{buy} + L_{non\text{-}buy}$ and $T = T_{buy} + T_{non\text{-}buy}$).

4.2 Description of a User Session in a Web Store

We describe a user session in a Web bookstore with session features. Some features concern HTTP-level information, like the number of HTTP requests processed by the server and the total volume of data (in KB) sent by the server to the Web client. Other features are directly connected with the user's activity on the e-commerce site throughout their visit: the number of Web pages opened by the user, duration of the session (in seconds), mean time per page (in seconds), or the user's activity in respect of such operations as logging on, adding an item to the shopping cart, and finalizing a purchase transaction (i.e., confirming an order). Furthermore, we included information about a source of the visit, corresponding to the way in which a user reached the bookstore site. The following sources were distinguished:

- a reference from an organic search engine result ($search_{org}$),
- a reference from a paid search engine result ($search_{paid}$),
- other reference from Google sites ($search_{other}$),
- an internal reference from other pages within the same website, e.g., from a page on which a user watched a video advertising a computer game (*internal*),
- direct entry (*direct*),
- other source (*other*).

Variables describing a user session are listed in Table 1. Eight first variables were converted to predictor variables to be used at the input of our neural network prediction model. The last variable was a dependent variable.

Table 1 Variables describing a user session in a Web store

No.	Variable	Variable description	Values
1	*PagesNo*	Number of Web pages	Int
2	*RequestsNo*	Number of HTTP requests	Int
3	*Duration*	Session duration	Int
4	*TimePerPage*	Mean time per page	Float
5	*TransferSize*	Total volume of data sent by the server	Int
6	*LoginNo*	Number of operations connected with the successful operation of user's logging on	Int
7	*AddNo*	Number of operations connected with adding an item to the shopping cart	Int
8	*Source*	Source of the visit meaning the way in which the user reached the online bookstore site	{$search_{org}$, $search_{paid}$, $search_{other}$, *internal*, *direct*, *other*}
9	*Purchase*	Indicator of whether a purchase transaction was successfully finalized or not	{0, 1}

4.3 Neural Network Model

We designed a multi-layered backpropagation neural network model consistent with Fig. 1. It was implemented as a C# program.

An input layer of the neural network consists of 14 neurons: one neuron is a bias equal to 1 and 13 neurons correspond to variables describing the session features 1–8. The variables numbered from 1 to 7 are quantitative variables taking numerical values so they were directly treated as input signals. The variable Source, however, is a nominal variable which may take one of six names. In order to map the nominal variable at the input of the neural network, six boolean variables, corresponding to the six possible nominal values, were created as additional input neurons. Ultimately, each user session was represented at the neural network input as a 13-element vector of predictor variables. Including the bias, the network input layer has 14 neurons.

The number of neurons in the output layer is equal to the cardinality of the training set, i.e., the number of buying and non-buying user sessions in the training set, |Lbuy| + |Lnon-buy|. Thus, evaluation of the network efficiency using the test set will give for each evaluated session i an array of values between -1 and 1, representing degrees of similarity of session i to each of the known samples.

The following prediction rule was experimentally determined. A purchase prediction for session *i* is assumed to be positive when the highest output value is for one of $|L_{buy}|$ outputs connected with the known buying sessions and at the same time output values for the remaining $|L_{non\text{-}buy}|$ outputs connected with the known non-buying sessions are all below 0.95. Otherwise a purchase prediction is assumed to be negative.

5 Experimental Results

5.1 Neural Network Training

The set of user sessions contained 33,354 samples (873 buying sessions and 32,481 non-buying ones). The training set L was created by drawing 11 samples from the set of all sessions: five buying sessions (making a subset Lbuy) and six non-buying sessions (a subset Lnon-buy). Thus, |Lbuy| = 5 and |Lnon-buy| = 6 gave 11 neurons in the output layer of the neural network. Values of variables describing buying and non-buying sessions used to train the network are presented in Tables 2 and 3, respectively.

We used the back-propagation learning algorithm and the hyperbolic tangent as the activation function. The stopping criterion was error rate below 5 % at each output.

The application of back-propagation to our neural network led to data overfitting. To cope with this problem we introduced the following procedure of

Table 2 Session feature values for buying sessions in the training set (*Purchase* = 1)

No.	Feature	Learning sample (session with a purchase made)				
		1	2	3	4	5
1	*PagesNo*	38	37	26	43	55
2	*RequestsNo*	301	280	300	237	739
3	*Duration*	1,725	533	1,239	691	1,266
4	*TimePerPage*	46.6	14.8	49.6	16.5	23.4
5	*TransferSize*	2,398.7	3,479.2	2,881.1	2,021.1	6,439.9
6	*LoginNo*	2	5	2	2	2
7	*AddNo*	1	1	1	2	0
8	*Source*	$search_{paid}$	$search_{other}$	$search_{other}$	*internal*	*Direct*

Table 3 Session feature values for non-buying sessions in the training set (*Purchase* = 0)

No.	Feature	Learning sample (session without a purchase)					
		1	2	3	4	5	6
1	*PagesNo*	3	101	23	26	2	2
2	*RequestsNo*	129	748	329	578	77	11
3	*Duration*	11	6,439	2,102	909	2	46
4	*TimePerPage*	5.5	64.4	95.6	36.4	2.0	46.0
5	*TransferSize*	1,163.2	10,463.1	5,051.7	5,277.6	590.4	106.1
6	*LoginNo*	0	1	0	0	0	0
7	*AddNo*	0	0	0	0	0	0
8	*Source*	$search_{paid}$	$search_{org}$	*direct*	$search_{paid}$	$search_{paid}$	$search_{org}$

modifying the learning samples during the training process. Every second sample drawing from L to be used in the successive training run was modified in such a way that: (1) a variable was drawn from all 13 predictor variables for the sample, (2) a way of modification was drawn (increase or reduction), and (3) the drawn variable of the sample was modified according to the drawn way of modification by 5 %. This modification of the training procedure significantly improved performance of our ANN model.

5.2 Neural Network Evaluation

Efficiency of the neural network was evaluated using the test set T which contained the remaining 33,343 sessions: 868 buying sessions (a subset T_{buy}) and 32,475 non-buying session (a subset $T_{non\text{-}buy}$). Sessions used to train the network were not used in its evaluation.

A prediction result for each evaluated session may be positive (when a purchase was predicted) or negative (no purchase prediction). The prediction result compared to the actual value of the *Purchase* variable for the session may be true or false.

Prediction results for all sessions may be then described with numbers of true and false positives (TP and FP, respectively) and true and false negatives (TN and FN, respectively). They may be presented in the form of a confusion matrix (Table 4), which columns represent prediction results and rows represent actual classifications, for all cases in the test set.

Final efficiency of our prediction model may be expressed with measures of accuracy, recall, and precision. Accuracy is the rate of all correct predictions:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{2}$$

Precision is the ratio of correct positive predictions to all positive predictions:

$$Precision = \frac{TP}{TP + FP} \tag{3}$$

Recall (sensitivity) reflects the probability of a correct positive prediction:

$$Recall = \frac{TP}{TP + FN} \tag{4}$$

Table 4 Confusion matrix of correct and incorrect predictions

	Predicted: No	Predicted: Yes
Actual: No	*TN*	*FP*
Actual: Yes	*FN*	*TP*

Table 5 Confusion matrix for the neural network

	No purchase prediction	Purchase prediction
Non-buying sessions	32,457	18
Buying sessions	106	762

5.3 Results and Discussion

Results of neural network evaluation using the test set are presented in a confusion matrix (Table 5). The following performance rates were achieved: Accuracy = 99.6 %, Precision = 97.7 %, and Recall = 87.8 %.

The neural network has very high prediction accuracy—it was able to make correct predictions for 99.6 % of all user sessions.

From the online retailer's point of view, however, a key measure will be recall as it means a probability of predicting that a user actually interacting with the site will decide to confirm an order. If this probability is correctly assessed, the retailer has a chance to apply a personalized service strategy aimed at converting visitors into buyers and increasing the conversion rate, e.g. by offering to some customers special discounts and incentives to finalize purchase transactions. Other possibility of using such an information is providing customers characterized by the high probability of making a purchase with better quality of service (QoS) in terms of service time (e.g., by request priority queuing) under the server overload. In this regard our model was able to achieve recall of almost 89 %, which is a promising result.

Precision of 97.7 % is very high. This measure gives an estimate of how many of users suspected of making purchases in their active sessions actually decide to make a purchase. High precision means that a possible misclassification of less promising customers as more valuable ones, resulting, e.g., in providing them with better QoS level under overload, will be a low risk for the online retailer.

6 Conclusions

Evaluation of the ANN model proposed in this paper has shown that the model was able to make correct predictions for 99.6 % of all user sessions. Its ability to predict purchases was not so high but also good (87.8 %).

To sum up, our results achieved for the proposed neural network model are promising, especially if one takes into account that only eleven samples were used in the network training. Further experiments with the higher number of training samples and session features, as well as with other network structures and parameters would probably further improve the neural network performance. We leave these issues to our future work.

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Searching for a Method of Basic Schedules Generation Which Influences Over the Performance of Predictive and Reactive Schedules

Iwona Paprocka and Wojciech M. Kempa

Abstract Two immune algorithms were selected in the process of searching for an algorithm which achieves a good quality basic schedule, i.e. Multi Objective Immune Algorithm (MOIA), Clonal Selection Algorithm (CSA). The two algorithms are applied for a multi criteria job shop scheduling problem. The basic schedules are modified using the rule of the Minimal Impact of Disturbed Operation on the Schedule (MIDOS) in order to generate predictive schedules. The influence of rescheduling policies over the performance of the job shop system is investigated using the rule of the Minimal Impact of Rescheduled Operation on the Schedule (MIROS). The three steps are proposed in order to achieve robust and stable schedules. In this paper the algorithms are presented. In the second paper (under the title of On the Quality of Basic Schedules Influencing over the Performance of Predictive and Reactive Schedules), the influence of the quality of basic schedules on the obtainment of stable and robust schedules with the application of the MIDOS and MIROS is investigated.

Keywords Immune algorithms · Multi-criteria optimisation · Predictive and reactive scheduling · Robust and stable schedules

1 Introduction

MANAGERS are searching for not only high-quality schedules but also for schedules that enable to react quickly to unexpected events and reorganize production plants in a cost-effective manner [1]. Lately, a great deal of effort has been

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spent developing methods to generate schedules dealing with an uncertainty. For example, in the following paper the research related to the minimization of the effect of disturbances are classified [2]. There are four research groups concerning the problem of updating production schedules: (1) repairing a schedule which has been disturbed, (2) complete rescheduling, (3) creating a schedule which is robust for a disturbance, (4) studies on the influence of rescheduling policies on the performance of a dynamic manufacturing system. The schedule repair consists in some local adjustment of the basic schedule. The complete rescheduling consists in generating a new schedule including not executed processes and new arrived. Regarding the first issue, the method based on the re-insertion of a disturbed process in the schedule, taking into account the alternative routes to generate the deadlock-free schedule is proposed in [3]. Regarding the second issue, Simulated Annealing (SA) and Dispatching Rule (DR) are used to minimize the total length of a schedule (makespan) in [4]. The schedule repair results in poor optimization performance comparing to the complete rescheduling. Regarding the third issue an algorithm generating a basic schedule and inserting a time buffer prior to a job with disturbance prediction is proposed in [5]. Predictive schedules generated with the use of this method can be inefficient taking into account the machine utilization criteria. Therefore, the authors of the paper intend to extend the studies on the influence of rescheduling policies on the performance of a production system.

Following techniques can be used for searching the solution space: exact methods and approximate methods. The second methods are divided into two groups: heuristics and metaheuristics. Exact techniques include among others: a complete theoretical search, branch and bound, linear and nonlinear programming, dynamic programming and graphs [6]. The exact methods require searching of the entire solution space. For this reason their use is limited to simple problems. The common feature of the metaheuristic and heuristic methods is information used to improve the efficiency of searching process [7]. The methods differ in the way of generating a new solution. In the heuristic methods, a single solution is modified to create a set of solutions. From the set, the best solution is selected. In the metaheuristic methods, a set of solutions is simultaneously modified in order to generate a new set of neighboring solutions. The metaheuristic methods are also called random methods.

Approximation algorithms (heuristic methods) achieve feasible solutions in an acceptable time. There are many heuristics based on priority rules used for solving scheduling problems. There are three groups of priority rules: local, global and hybrid priority rules. The local priority rules priorities the operations of a process (e.g. Shortest Processing Time—SPT, Longest Processing Time—LPT). The global priority rules are concerned with processes (e.g. First Come First Served—FCFS and Last Come First Served—LCFS [8].). The hybrid priority rules are concerned with a certain number of operations of the process (e.g. Most Work Remaining—MWR, and Least Work Remaining—LWR) [9].

Simulated Annealing, Tabu Search algorithms, Ant Colony Optimisation Algorithms, Evolutionary Algorithms (EA), Immune Algorithms (IA), Genetic Algorithms (GA) and algorithms that use the Fuzzy Logic belong to the

meta-heuristic techniques. 'Biological optimisation algorithms' are commonly used for solving scheduling problems. Often, GA and hybrid GA are better than algorithms, such as: TS, SA because of the random nature of generating solutions and searching processes regardless of a size of a scheduling problem [9]. Hybrid GA achieves much better solutions by maintaining a strong selection pressure, while avoiding the premature convergence of populations to a local optimum [9]. The application of GAs for solving basic scheduling problems is a commonly used approach [10]. IAs achieve a little less popularity [11–13].

GA and IA belong to meta-heuristic methods that achieve satisfying solutions, but not the optimal. Under the conditions of competitive market, managers do not need the optimal solution; they need a one which is good enough and meets given constraints and criteria. Moreover, a complex manufacturing environment causes that researches on scheduling issues are not concentrated on a single criterion. Managers evaluate schedules using multiple criteria, since the competitive market has strong influence over a quantity and quality of products executed in their companies. In recent years, time of obtaining a satisfying schedule is minimized, so the problem of elaborating an algorithm which achieves satisfying schedule in a reasonable time, predefined by a manager, is still up-to-day [14, 15]. Due to the combinatorial nature of scheduling problems and multi-dimensional searching space, immune algorithms are selected to solve the basic schedule generation problem.

The architecture of the immune algorithm (Hybrid-Multi Objective Immune Algorithm (H-MOIA)) consists of three steps: a basic schedule generation, predictive schedule generation and reactive schedule generation. Thus the following question arises: does the quality of the basic schedule influence on the performance of predictive and reactive schedules generated in the second and third steps of the H-MOIA respectively. In the H-MOIA, basic schedules are generated using an immune algorithm which is one of possible techniques to apply for searching a complex solution space.

Searching for an effective algorithm (the algorithm which achieves a good quality basic schedule within predefined time) two immune algorithms are compared: MOIA and Clonal Selection Algorithm (CSA). Each algorithm generates the Pareto curve which give information about possible trade-offs between four objective functions, makespan minimization $C_{\max} \rightarrow \min$, total tardiness minimization $T \rightarrow \min$, total flowtime minimization $F \rightarrow \min$, total idle time of machines minimization $I \rightarrow \min$. The best schedule is selected from the Pareto-optimal solution set using the scalar fitness function [16].

On the basis of the overview of reference publications, the following research points have been identified:

(1) methods of generating basic schedules enabling the obtainment of the best performance of the job shop system when the objective is to minimise: makespan, flow time, total tardiness and idle time.
(2) methods of generating basic schedules enabling the obtainment of stable and robust schedules in the second stage of H-MOIA.

The paper is organized as follows: two immune algorithms for basic scheduling are presented in the next Section: the MOIA and CSA. Basic schedules are the input data to the second stage of the H-MOIA in order to generate robust (predictive) schedules. Predictive schedules undergo a rescheduling heuristic in order to evaluate the stability and robustness performance. Heuristics for predictive and reactive scheduling are presented in Sect. 3. The paper concludes with experiments schedule (Sect. 4). The results of the experiments are described in the paper under the title "On the Quality of Basic Schedules Influencing over the Performance of Predictive and Reactive Schedules". In the paper, the influence of the quality of basic schedules over the obtainment of stable and robust schedules is investigated.

2 A Basic Schedule Generation

Searching for an algorithm which achieves good quality basic schedules, for a multi criteria job shop scheduling problem, two immune algorithms are compared: Multi Objective Immune Algorithm (MOIA), Clonal Selection Algorithm (CSA). In the both algorithms, a pathogen represents a scalar fitness function, and antibodies correspond to solutions of the multi criteria job shop scheduling problem. The best solution of the problem is represented by the schedule with the minimal value of the scalar fitness function.

2.1 The Multi Objective Immune Algorithm

The MOIA consists of the following modules: data interface, antibodies coding, multi criteria immune optimisation and antibodies decoding. Two stages are distinguished in the immune optimisation module. The first one mimics the exogenous activation and the second one corresponds to the endogenous activation of the immune system.

- The exogenous activation is stimulated by a temperature parameter. Also, the pathogen presence fuels the defending reaction of the immune system. This phenomenon is used in order to achieve a promising search direction (a vector of weights of criteria) in a multi-criteria solutions space.
- In the endogenous activation, antibodies recognizing the pathogen produce offspring (in the process of clonally proliferation). Offspring undergo a mutation in order to better match to the pathogen. A diversity of produced offspring is controlled in the processes of stimulation (similar antibodies activation) and suppression (similar antibodies elimination).

The first immune response is carried out by the exogenous and endogenous activation and is triggered by a pathogen which invades the body for the first time.

Step 1: Genes coding in the DNA Library
While number of iterations L is higher than 0 in the endogenous population do
Step 2: Generate a search direction ω
  While L is higher than 0 do
  Step 3: Generate a new IP
  Step 4: For given ω evaluate the IP using the average fitness function $\overline{\overline{FF}}$
  Step 5: Memorize the best IP for the search direction ω, $\overline{FF}(IP) \geq \overline{FF}(IP^*) + Tt$, $IP^* \leftarrow IP$
While number of iterations $Ł$ is higher than 0 in the exogenous population do
Step 6: Divide IP into sub-populations;
For each sub-population (each criterion) Θ_o, $o = 1,2,...,O$, do:
Step 7: Crossover, elite selection, mutation, elite selection
For sub-population for the scalar function Θ_{o+1}, do:
Step 8: Hypermutation, elite selection to create a new sub-population Θ^*_{o+1}
Step.9: Combine sub-populations $\Theta_1 \ldots \Theta_o$ for each criterion to generate a new sub-population Θ^*
Step 10: Stimulation process between antibodies in population Θ^*
Step 11: Suppression process between antibodies in population Θ^*
Step 12: Selection process between antibodies in populations Θ^* and Θ^*_{o+1} to create a new IP
Step 13: Memorize the best solution p^* from the new IP in immune memory IM
Step 14: Secondary immune response

Fig. 1 Pseudo code of the MOIA algorithm

Some of well-binding antibodies to the pathogen survive and are transformed into memory cells for destroying the pathogen more effectively in the secondary immune response. The pseudo code of the MOIA is presented in Fig. 1 [17, 18]. The parts of the algorithm are explained in following subsections.

Encoding and Decoding
In job shops, job-based representation is common scheme to encode a solution. Each antibody is assumed to be a precedence feasible order of production tasks as a solution representation scheme. The order of a production task is random generated between (1 and a total number of production tasks accepted for realization). By scanning the permutation from left to right, the occurrence of production task number (gene) indicates the priority of the task. To transform antibody to a feasible solution a production task (according to the permutation) is scheduled at the earliest feasible time according to the precedence and resource constraints.

Initialization
A set of randomly generated solutions serves as the initial population IP. Since the performance of the algorithm and the quality of the obtained schedules is sensitive to the quality of the IP, we incorporate heuristic procedures that are applied to the initial population. Three initial solutions are generated using priorities rules: the Least Processing Time (LPT), Earliest Due Date (EDD) and Random Insertion Perturbation Scheme (RIPS) [1].

Search Direction
The promising search direction is the vector of criteria weights ω, for which the best IP is achieved. Vectors of weights and antibodies in IP are generated at random and the average fitness function $\overline{\overline{FF}}$ is computed until the stopping criterion (L) is met. The promising vector of weights ω is memorized for the IP which quality is better than the predefined threshold (the temperature parameter *Tt*) comparing to the previous $\overline{\overline{FF}}$. This step is omitted, when the decision-maker defines priorities of criteria (for a constant ω). The reduction of computation time is the advantage of searching for the best vector of weights. This approach is also used because it prevents the algorithm from being trapped in a specific region of the search area.

Affinity Maturation
The Job Based Crossover and Displacement Mutation procedures are employed in sub-population Θ_o for the purpose of the affinity maturation. Hypermutation procedure is employed in sub-population Θ_{o+1} for the purpose of the affinity maturation. Dependent on the scalar fitness function value, each antibody suffer different range of mutation. The inferior antibodies undergo a high rate of hypermutation whereas better antibodies suffer a slight change. As high rate hypermutation, the Shift Mutation is repeated three times. Better solution is selected from the pair of antibodies before and after affinity maturation in the elite selection procedure.

Stimulation and Suppression
Similar antibodies are identified in sub-population Θ^* in the stimulation process. Let antibody p_k belong to a neighborhood $N(p_k)$. Antibody p_{k+1} belongs to the $N(p_k)$ under the constraint that the affinity between p_k and p_{k+1} is lower than or equal to affinity threshold Td. The affinity between p_k and p_{k+1} is computed using the Hamming distance. The neighborhood reduction is performed in sub-population Θ^* in the suppression process. A number of similar antibodies belonging to the $N(p_k)$ need to be lower than suppression threshold Ts. The process of reduction of identical antibodies helps to maintain high diversity of solutions.

Secondary Immune Response
The best solution p^* is directly copied into immune memory IM in each generation. Neighboring regions of antibodies p^* are searched during the secondary immune response. The local search is performed using mutation operators, Shift Mutation, Insertion Mutation, and Reciprocal Exchange Mutation. The explanation for the fact of using the secondary immune response is higher chance for the algorithm to explore a local search area.

2.2 The Clonal Selection Algorithm

In the Clonal Selection Immune Algorithm (CSIA) stimulated antibodies produce clones. Clones are differentiated by the hypermutation operator. A clone survives if it recognizes the pathogen (a paratope of the antibody matches to an epitope of the pathogen), in other case, the clone is removed from the body (apoptosis). Steps of the CSIA are presented in Fig. 2 [19].

Step 1: Genes coding in the DNA Library
Step 2: Generation of immune memory η
While number of iterations L is higher than 0 in the clonal selection process do

Step 3: Evaluate antibodies p_η from the η using the fitness function to the pathogen, $FF(p_\eta)$
Step 4: For each criterion o, $(o=1,2,...,O)$, clone the *IM* in order to create C
Step 5: Hypermutation in order to create a new population C^*
Step 6: Stimulation process in order to indentify the best matched clone c_k^* for each antibody p_η form the IM
Step 7: $p_\eta \leftarrow c_k^*$ if $FF(c_k^*) < FF(p_\eta)$ in the selection process
Step 8: Identify well-matched antibody $p_\eta^* \in \eta$ for each antibody $p_\eta \in \eta$ in the suppression process
Step 9: $p_\eta \leftarrow p_\eta^*$ if $FF(p_\eta^*) < FF(p_\eta)$ in the elite selection procedure to generate a new η

Fig. 2 Pseudo code of the CSA algorithm

Input parameters of the CSIA are as follows: a size of immune memory η, number of iterations L, number of clones C, affinity threshold Td.

The first step of the CSIA is the same as in the MOIA in order to make possible the application of the CSIA for the job shop scheduling problem (JSP) and the comparison between the two algorithms. The size of the immune memory does not change through the whole pathogen recognition process using the CSIA.

Each antibody (from immune memory η) produces a fixed number of clones. The size of the population of clones C equals to $K = \eta \times O$. O states as the number of criteria used in the evaluation process. Clones undergo the hypermutation procedure in order to create a new population of clones C*.

In the stimulation process, the best-matched clone ck* ∈ C* is searched for each antibody pη ∈ η. Let antibody pη and clone ck belong to neighborhood N(pη). Clone ck* is the best-matched to antibody pη if the Hamming distance between them is the shortest.

The antibody $p_\eta \in \eta$ and the best-matched clone c_k^* are evaluated using fitness function FF. p_η is replaced by c_k^* if $FF(c_k^*) < FF(p_\eta)$ in the selection process.

A well-matched antibody is searched for each antibody $p_\eta \in \eta$ in the suppression process. Antibody $p_{\eta+1}$ is well-matched if the Hamming distance between them is shorter than or equal to Td. p_η is replaced by the best matched p_η^* if $FF(p_\eta^*) < FF(p_\eta)$.

The superior antibody survives from the two: p_η and p_η^* in immune memory η. The inferior solution is replaced by a new one, generated at random. The searching process is terminated after a predefined number of iterations L.

The MOIA and CSA are applied for basic schedules generation for a job shop scheduling problem.

3 Predictive and Reactive Schedules Generation

The first step consists in generating a basic schedule using the MOIA or CSA. The second step consists in applying the rule of Minimal Impact of Disturbed Operation on the Schedule (MIDOS). For the bottleneck a maintenance work is introduced at the time of predicted failure, MTTF [20]. The MIDOS is computed for operations that have the bottleneck as the parallel machine. The operation of the process, which is the most flexible and which disruption causes as few changes as possible in the schedule, is firstly assigned to the bottleneck at the time of increased probability of failure. Backward and forward scheduling is applied for remaining operations of the process [21].

Reactive schedules are generated in the third step in the method analyzed in this paper. The reactive schedule consists in using the heuristic of Minimal Impact of Rescheduled Operation on the Schedule (MIROS). In this heuristic two rescheduling methods are applied: (1) Right Shifting (RSh), (2) rescheduling of disturbed operations on parallel machines firstly available (RDO). Reactive schedules are evaluated using two criteria, stability and robustness. In the MIROS

the influence of rescheduling policies over the performance of a production system is evaluated and the best compromise solution is selected.

4 Summary

In this paper two immune algorithms were presented for the basic schedule generation: the MOIA and CSA. In the next paper, the two algorithms are applied for the job shop scheduling problem. The job shop scheduling problem is well-known hard combinatorial optimization problem [8]. Many research are concerned with multi-objective basic schedule generation problem, nonetheless no method enabling achieving the optimal solution has been found [22]. In this paper the idea to develop the basic schedules into the predictive schedules is presented. Also the strategy of studying on the influence of rescheduling policies over the efficiency of the predictive schedules is proposed.

Basic schedules are evaluated using criteria: makespan, flow time, total tardiness and idle time. The basic schedules with the best performance of the job shop system are selected for the two algorithms. Achieved schedules are modified to generate predictive schedules using the MIDOS. The predictive schedules are evaluated using also the four criteria mentioned above. In order to evaluate the stability and robustness of the predictive schedules the MIROS is applied.

The influence of the quality of basic schedules over the quality of predictive and reactive schedules is investigated in the paper under the title of "On the Quality of Basic Schedules Influencing over the Performance of Predictive and Reactive Schedules".

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On the Quality of Basic Schedules Influencing over the Performance of Predictive and Reactive Schedules

Iwona Paprocka

Abstract Searching for an algorithm which achieves good quality basic schedules, in predefined time, two immune algorithms are compared, Multi Objective Immune Algorithm (MOIA), Clonal Selection Algorithm (CSA). In the MOIA two stages are distinguished, the first stage mimics the exogenous activation and the second corresponds to the endogenous activation of an immune system. The architecture of CSIA mimics the clonal proliferation and maturation processes. The two algorithms are applied for a multi criteria job shop scheduling problem. Basic schedules are modified using the rule of Minimal Impact of Disturbed Operation on the Schedule (MIDOS) in order to generate predictive schedules. The influence of rescheduling policies over the performance of a job shop system is investigated using the rule of Minimal Impact of Rescheduled Operation on the Schedule (MIROS). In the paper, the influence of the quality basic schedules over the obtainment of stable and robust schedules with the application of the MIDOS and MIROS is investigated.

Keywords Immune algorithms · Multi-criteria optimisation · Predictive and re-active scheduling · Robust and stable schedules · Maintenance

1 Introduction

The quality of obtained schedules relates to the efficiency of production activities. Production schedules help managers and supervisors to coordinate production tasks in order to increase productivity and to reduce production costs [1].

Many studies on scheduling problems deal with the problem of disturbances of machine operation [2]. Especially, the failure of the bottleneck can trigger overtime production, in-process subcontracting, process re-routing, set-up times increasing.

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The problem of scheduling under the condition of uncertainty relates to the minimization of changes introduced to the basic schedule and new realization on the shop floor. In the following paper the attempt to classify measures related to the effect of disturbances is undertaken [3]. The measures are classified into four groups: measures of schedule efficiency, measures of schedule stability (nervousness), measures of schedule robustness and cost. Measures of schedule efficiency and cost are used to evaluate basic schedules (nominal schedules) in static and deterministic environment. Measures of schedule stability and robustness are used to evaluate a schedule in stochastic or dynamic environment. Moreover measures of schedule efficiency and cost can be combined with schedule stability or robustness. Wu et al. [4] evaluate a schedule using any criterion measuring efficiency and the schedule stability. Unfortunately, optimising the efficiency criterion usually results in major deterioration of the stability criterion [5].

Originally, schedule stability means a schedule nervousness or instability. Schedule stability is measured using e.g.:

- the number of revisions or changes which are done for a schedule,
- the number of disturbances in the system [5],
- the sum of absolute deviations of the starting times of the remaining operation in the reactive and basic schedule [6]. The result can be divided by the value obtained by multiplying number of remaining jobs by the number of machines [5].

The higher stability is, the better the performance of the reactive schedule is [5].

Schedule robustness measures the degradation of the performance (efficiency measures) of a production system due to a disturbance. A schedule robustness is defined as the performance of the schedule insensitive to the disturbance [7, 8].

Schedule robustness measures the efficiency of reactive schedules. The schedule robustness is measured using e.g.:

- the comparison of the makespan of the revised and the basic schedule,
- the comparison of the scalar fitness function of four objectives (makespan, total tardiness, flow time and idle time) of the revised and the basic schedule [6],
- the comparison of the makespan of the revised and the basic schedule divided by the makespan of the basic schedule. The result is subtracted from 1 and multiplied by 100 %. Thus the quality of reactive schedule can receive a value which is equal or higher than 100 %. It means that makespan of the reactive schedule can obtain a value which is equal or lower than the value of the basic schedule [5].

Vieira et al. [3] classify measures related to the effect of disturbances over a schedule or a production system. Stability measures are used to measure the changes to a schedule and robustness measures are used to measure the changes to production system performance.

During the execution of production processes the two following disruptions can occur: possible to predict and impossible to predict [9, 10]. Any event which is

possible to predict should be planned in the basic schedule. The more changes in the basic schedule the lower stability and robustness of the schedule are. Cost of reorganization of the production schedule increases and time is wasted.

On the basis of the overview of reference publications, the following research points have been identified:

1. methods of generating basic schedules enabling the obtainment of the best performance of the job shop system when the objective is to minimise: makespan, flow time, total tardiness and idle time.
2. methods of generating basic schedules enabling the obtainment of stable and robust schedules in the second step of H-MOIA.

The first paper under the title of "Searching for a Method of the Basic Schedule Generation which influences over the Performance of Predictive and Reactive Schedules" presents two immune algorithms for basic scheduling: Multi Objective Immune Algorithm (MOIA), Clonal Selection Algorithm (CSA). Also, the heuristics for predictive and reactive scheduling are presented in the first paper: Minimal Impact of Disturbed Operation on the Schedule (MIDOS) and Minimal Impact of Rescheduled Operation on the Schedule (MIROS). In this paper, the influence of the quality of basic schedules over the obtainment of stable and robust schedules with the application of the MIDOS and MIROS is investigated.

The paper is organised as follows: a job shop scheduling problem is described in the next Section. Experimental input data are given in Sect. 3. Experimental results are presented in Sect. 4. The paper concludes with a brief summary of the achievements (Sect. 5).

2 A Job Shop Scheduling Problem

A production system is described as follows: a number of jobs I, $i = 1, 2, \ldots I$ is executed on a number of machines M, $m = 1, 2, \ldots$ M. Each job consists of a number of operations J, j = 1, 2, …, J, $p_{i,j}$ denotes the processing time of operation j of job i on machine m. A workflow is not unidirectional. Each machine can be input and output of the workflow. There are precedence relations between operations. Following constraints are imposed for operations:

- operation precedence constraints for a given job—at any time, at most one operation of a job can be executed;
- exclude-like mode—at any time, at most one operation can be executed on each machine.

After a machine failure disturbed operations are rescheduled on parallel machines.

In the job shop scheduling problem the objective is to find a feasible schedule so that it optimizes objective functions: makespan $C_{max} \rightarrow$ min; total tardiness T →

min; flow time F → min and idle time I → min. Moreover the objective is to find a stable and robust schedule in the event of machine failure.

3 Experimental Input Data

The route of process *i* is described in the Matrix of Processes Routes (MPR) (1). Processing time of operation j is predefined in the Matrix of Operations Times (MOT) (2). In MPR and MOT, a row denotes a number of job i, and a column denotes a number of machine *m* on which operation j must be executed. Let we consider the first row of the MPR. The first process consists of 15 operations (1). The first operation of the first process is processed on the first machine, the second operation of the first process is processed on the second machine and so on.

According to the MOT (2) processing time of 1st operation of 15th process equals 1 (15th row and 10th column), processing time of 2nd operation of 15th process equals 2 (15th row and 3rd column).

Due date d_i of job *i* is described in the Vector of Due Dates (VDD) (3). The due date of the first process equals 110 (1st column), and due date of the second process equals 100 (2nd column) and so on. Batch size b_i of job *i* is predefined in the Vector of Batch Size (VBS) (4).

$$MPR = \begin{bmatrix} \text{MPR0} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 \\ \text{MPR1} & 1 & 2 & 3 & 4 & 5 & 6 & 8 & 7 & 9 & 10 \\ \text{MPR2} & 1 & 2 & 3 & 4 & 5 & 6 & 8 & 7 & 9 & 10 \\ \text{MPR3} & 1 & 2 & 3 & 4 & 5 & 6 & 8 & 7 & 9 & 10 \\ \text{MPR4} & 1 & 2 & 3 & 4 & 5 & 6 & 8 & 7 & 9 & 10 \\ \text{MPR5} & 1 & 2 & 3 & 4 & 5 & 9 & 10 & 6 & 8 & 7 \\ \text{MPR6} & 1 & 2 & 3 & 4 & 5 & 8 & 7 & 6 & 9 & 10 \\ \text{MPR7} & 1 & 2 & 3 & 4 & 5 & 8 & 7 & 6 & 9 & 10 \\ \text{MPR8} & 1 & 2 & 3 & 4 & 5 & 6 & 8 & 7 & 9 & 10 \\ \text{MPR9} & 1 & 2 & 3 & 4 & 5 & 6 & 8 & 7 & 9 & 10 \\ \text{MPR10} & 1 & 2 & 3 & 4 & 5 & 9 & 10 & 6 & 8 & 7 \\ \text{MPR11} & 1 & 2 & 3 & 4 & 5 & 8 & 7 & 6 & 9 & 10 \\ \text{MPR12} & 1 & 2 & 3 & 4 & 5 & 8 & 7 & 6 & 9 & 10 \\ \text{MPR13} & 5 & 8 & 9 & 10 & 3 & 4 & 1 & 2 & 6 & 7 \\ \text{MPR14} & 3 & 4 & 2 & 6 & 7 & 8 & 9 & 10 & 5 & 1 \end{bmatrix} \quad (1)$$

$$MOT = \begin{bmatrix} \text{MOT0} & 5 & 4 & 1 & 4 & 1 & 1 & 2 & 3 & 4 & 5 \\ \text{MOT1} & 5 & 2 & 4 & 4 & 1 & 1 & 2 & 3 & 4 & 5 \\ \text{MOT2} & 5 & 1 & 2 & 4 & 1 & 1 & 2 & 3 & 4 & 5 \\ \text{MOT3} & 4 & 1 & 1 & 4 & 2 & 1 & 1 & 1 & 1 & 1 \\ \text{MOT4} & 5 & 1 & 2 & 4 & 1 & 2 & 2 & 2 & 2 & 2 \\ \text{MOT5} & 4 & 1 & 1 & 4 & 2 & 1 & 1 & 2 & 2 & 3 \\ \text{MOT6} & 5 & 1 & 2 & 4 & 1 & 2 & 2 & 2 & 2 & 2 \\ \text{MOT7} & 4 & 1 & 1 & 4 & 2 & 1 & 2 & 1 & 2 & 1 \\ \text{MOT8} & 5 & 2 & 1 & 4 & 1 & 3 & 2 & 3 & 2 & 3 \\ \text{MOT9} & 5 & 3 & 2 & 4 & 1 & 1 & 2 & 1 & 2 & 1 \\ \text{MOT10} & 4 & 1 & 1 & 4 & 2 & 1 & 1 & 2 & 2 & 3 \\ \text{MOT11} & 5 & 1 & 2 & 4 & 1 & 2 & 2 & 2 & 2 & 2 \\ \text{MOT12} & 4 & 1 & 1 & 4 & 2 & 1 & 2 & 1 & 2 & 1 \\ \text{MOT13} & 5 & 2 & 1 & 4 & 1 & 3 & 2 & 3 & 2 & 3 \\ \text{MOT14} & 5 & 3 & 2 & 4 & 1 & 1 & 2 & 1 & 2 & 1 \end{bmatrix} \quad (2)$$

$$VDD = [110\,100\,50\,110\,110\,50\,110\,110\,120\,120\,150\,210\,210\,220\,220] \quad (3)$$

$$VBS = [2\,2\,1\,1\,2\,1\,1\,1\,2\,2\,1\,2\,1\,2\,1] \quad (4)$$

$$MPM = \begin{bmatrix} \text{MPM0} & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 & 0 \\ \text{MPM1} & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 \\ \text{MPM2} & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ \text{MPM3} & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 0 \\ \text{MPM4} & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \\ \text{MPM5} & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ \text{MPM6} & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ \text{MPM7} & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 \\ \text{MPM8} & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 0 & 1 \\ \text{MPM9} & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\ \text{MPM10} & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ \text{MPM11} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ \text{MPM12} & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \text{MPM13} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \dots \end{bmatrix} \cdot \begin{bmatrix} \dots \\ \text{MPM136} & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 \\ \text{MPM137} & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ \text{MPM138} & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 0 \\ \text{MPM139} & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \\ \text{MPM140} & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ \text{MPM141} & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ \text{MPM142} & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ \text{MPM143} & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\ \text{MPM144} & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 \\ \text{MPM145} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \text{MPM146} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \text{MPM147} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \text{MPM148} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \text{MPM149} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} .. \quad (5)$$

The objective is to achieve the best compromise schedule for 15 processes executed on 10 machines, for four objective functions: $C_{max} \rightarrow$ min; T$\rightarrow$ min; F $\rightarrow$ min and I$\rightarrow$min. In order to make possible the comparison of the two algorithms, a decision maker defined the priorities of criteria. The priority (weight) of 1st and 3rd criterion equals 0.3, the priority of 2nd and 4th criterion equals 0.2.

The first machine is the most loaded machine. The increased probability of the bottleneck failure is indicated at the time horizon: [a, b + MTTR] where: a = 60 and b = 72 and, MTTR = 6. The failure free time of the bottleneck MTTF equals 66. After a disturbance each operation vj can be rescheduled on a machine from a set of parallel machines described in the Matrix of Parallel Machines (MPM) (5).

A row of the MPM describes a set of parallel machines for operation vj primarily assigned to machine w, and is calculated from $(j-1)\cdot W + w_v$.

The question arising in such a situation is: do the methods of generating basic schedules influence over the stability and robustness of predictive and reactive schedules generated in the second and third step of the H-MOIA? In the next Section the results of computer simulations with the application of the MOIA and CSA, for the basic scheduling problem are presented. The influence of the quality of basic schedules over the quality of predictive and reactive schedules is investigated.

4 Results of Computer Simulations

In the MOIA, input parameters are as follows: size of a sub-population for a single objective scheduling problem, z = 6; the size of the initial population for the multi-criteria scheduling problem, Y = z • O = 6 • 4 (O is the number of objective functions), y = 1, 2, …Y (y—an antibody); the number of iterations in the endogenous population, Ł = 0. The endogenous response of the MOIA is not activated since the vector of searching was predefined by a decision maker. Remaining input parameters are as follows: the number of iterations (terminal condition) in the exogenous population, L = 30; the maximal number of genes undergoing mutation in the hypermutation process = 2; the affinity threshold (used for determining the similarity of one antibody to another), affthres = 8; the stimulation threshold (used for determining the number of similar solutions which can exist in the exogenous population), stimthres = 3.

In order to achieve the basic schedule for JS problem (10 × 15) using the MOIA, six simulations were run for the input data presented in Sect. 3. In the first simulation, the best basic schedule was generated according to the rule of {2 5 14 1 3 0 4 6 7 10 8 9 11 12 13}. The quality of the priority list based schedule is Cmax = 117, F = 511, I = 638 and T = 0. Remaining solutions are described in Table 1. Also, three simulations were run for affthres = 80 and the remaining input data presented above. In the first simulation, the best basic schedule was generated according to the rule of {5 14 6 3 2 0 4 7 1 8 9 10 11 12 13}. The quality of the

Table 1 The best basic schedules achieved by the **MOIA** and for *affthres* = 8

No simulation	Job shop scheduling problem (15 × 10)					
	The priority rule of the basic schedule	The quality of the schedule				
		C_{max}	F	I	T	FF_y
1	2 5 14 1 3 0 4 6 7 10 8 9 11 12 13	117	511	638	0	264.9
2	**10 14 2 5 3 1 0 4 7 8 9 6 11 12 13**	**117**	**493**	**638**	**0**	**261.3**
3	2 5 8 0 14 1 4 3 6 7 9 10 11 12 13	117	534	638	0	269.5
4	5 2 13 14 0 3 4 6 7 1 8 9 10 11 12	121	461	678	0	264.1
5	2 10 5 14 0 1 3 4 7 8 9 6 11 12 13	117	525	638	0	267.7
6	2 5 8 14 1 3 0 4 6 7 10 11 12 9 13	117	521	638	0	266.9

Table 2 The best basic schedules achieved by the **MOIA** and for *affthres* = 80

No simulation	Job shop scheduling problem (15 × 10)					
	The priority rule of the basic schedule	The quality of the schedule				
		C_{max}	F	I	T	FF_y
1	5 14 6 3 2 0 4 7 1 8 9 10 11 12 13	117	508	638	0	264.3
2	**2 5 14 1 0 4 8 9 3 6 7 10 12 11 13**	**117**	**496**	**638**	**0**	**261.9**
3	2 14 3 8 7 13 5 10 6 4 1 0 9 11 12	121	458	678	0	263.5
4	2 5 1 13 14 10 0 3 6 4 7 8 9 11 12	121	540	678	0	279.9
5	2 10 5 0 14 4 3 7 1 8 9 6 11 12 13	117	527	638	0	268.1
6	2 5 8 14 1 0 3 4 7 9 6 10 11 12 13	117	527	638	0	268.1

priority list based schedule is Cmax = 117, F = 508, I = 638 and T = 0. Remaining solutions are described in Table 2.

Using the MOIA, the best basic schedule was generated in the second simulation for both *affthres* = 8 and for *affthres* = 80. Taking into account experimental results achieved for *affthres* = 8, the quality of the best basic schedule equals to FF_y = 261.3. Therefore, the predictive and reactive schedules will be generated using the example of the rule of {10 14 2 5 3 1 0 4 7 8 9 6 11 12 13}. Taking into account solutions achieved for *affthres* = 80, the quality of the best basic schedule equals to FF_y = 261.9. Therefore, the issue will be generated using the example of the rule of {2 5 14 1 0 4 8 9 3 6 7 10 12 11 13}.

In order to achieve the basic schedule for JS problem (10 × 15) using the CSA, six simulations were run for the input data: the size of the immune memory η = 10, number of iterations L = 30, size of the population of clones C equals to K = 40 and affinity threshold Td = 8.

In the first simulation, the best basic schedule was generated according to the rule of {9 8 4 10 0 7 5 2 6 1 3 11 13 12 14}. The quality of the schedule is Cmax = 123, F = 702, I = 698 and T = 89. Remaining solutions are described in Table 3.

Also, six simulations were run for Td = 80 and the remaining input data presented above. In the first simulation, the best basic schedule was generated

Table 3 The best basic schedules achieved by the **CSA** and for *Td* = 8

No simulation	Job shop scheduling problem (15 × 10)					
	The priority rule of the basic schedule	The quality of the schedule				
		C_{max}	F	I	T	$FF(p_\eta)$
1	9 8 4 10 0 7 5 2 6 1 3 11 13 12 14	123	702	698	89	343.6
2	3 6 4 8 13 7 0 2 1 11 9 12 5 10 14	127	584	738	111	335.8
3	**7 4 2 0 6 5 8 1 11 12 14 3 9 13 10**	**122**	**567**	**688**	**12**	**291.2**
4	11 2 14 13 10 1 12 3 8 0 4 6 5 7 9	124	583	708	27	303.5
5	9 1 11 5 2 4 8 0 14 6 3 10 12 13 7	130	640	768	36	331.4
6	8 3 0 11 5 13 2 14 4 9 10 1 7 6 12	130	514	768	162	344

Table 4 The best basic schedules achieved by the **CSA** and for $Td = 80$

No simulation	Job shop scheduling problem (15 × 10)					
	The priority rule of the basic schedule	The quality of the schedule				
		C_{max}	F	I	T	$FF(p_\eta)$
1	12 13 0 7 11 14 9 5 6 4 10 8 2 3 1	133	547	798	122	345.5
2	7 10 4 14 11 6 9 1 12 5 13 2 3 0 8	131	543	778	130	342.5
3	14 5 4 9 13 3 7 10 1 2 11 6 12 8 0	134	494	808	78	324
4	**5 1 3 14 9 2 10 8 4 11 6 0 12 7 13**	**124**	**534**	**708**	**27**	**293.7**
5	1 11 9 7 5 10 2 14 3 8 13 6 12 0 4	130	640	768	36	331.4
6	12 3 0 11 13 7 14 9 1 4 8 2 10 5 6	130	514	768	162	344

according to the rule of {12 13 0 7 11 14 9 5 6 4 10 8 2 3 1}. The quality of the schedule is Cmax = 133, F = 547, I = 798 and T = 122. Remaining solutions are described in Table 4.

Using the CSA, the best basic schedule was achieved in the third simulation for $Td = 8$. The quality of the basic schedule $FF(p_\eta)$ equals 291.2. Therefore, the predictive and reactive schedules will be generated using the example of the rule of {7 4 2 0 6 5 8 1 11 12 14 3 9 13 10}. The best basic schedule was achieved in the fourth simulation for $Td = 80$. The quality of the basic schedule $FF(p_\eta)$ equals 293.7, thus, the issue will be analysed using the rule of {5 1 3 14 9 2 10 8 4 11 6 0 12 7 13}.

In the next Section, the experimental results of computer simulations using the second and third step of the H-MOIA are given.

4.1 MIDOS

First, the PS is generated using the second stage of the H-MOIA. Input data to the second stage of H-MOIA + MIDOS constitute the basic schedules generated by the MOIA and CSA (Table 5). It was predicted that operations performed on machine $w = 1$ can be disturbed in the time period [a, b + MTTR]. Disturbed batches $\hat{s}_j$ are deleted from the basic schedule.

In the PS, the technical inspection of the bottleneck is scheduled at the time period [MTTF, MTTF + MTTR] = [66, 66 + 6]. Next, the most flexible operation of each deleted job is scheduled in the time period [60, 72 + 6] $\notin$ [MTTF, MTTF + MTTR]. For the remaining operations, backward and forward scheduling algorithms are applied. The quality of predictive schedules obtained at the second stage of the H-MOIA, is presented in Table 5.

Table 5 The influence of a basic scheduling method over the quality of predictive schedules achieved for the JS problem (15 × 10)

No	Basic scheduling method	Predictive scheduling method	The priority rule of the basic schedule	*Cmax*	*F*	*T*	*I*	*FFy*
1	MOIA	MIDOS	10 14 2 5 3 1 0 4 7 8 9 6 11 12 13	110	611	0	562	267.6
2			2 5 14 1 0 4 8 9 3 6 7 10 12 11 13	111	669	0	572	281.5
1	CSA	MIDOS	7 4 2 0 6 5 8 1 11 12 14 3 9 13 10	116	613	11	622	285.1
2			5 1 3 14 9 2 10 8 4 11 6 0 12 7 13	120	656	19	662	305.3

Table 6 The influence of a basic scheduling method over the quality of reactive schedules achieved for the JS problem (15 × 10) (where: PS—predictive scheduling, RS—reactive scheduling)

No	Basic + PS method	RS method	The priority rule of the basic schedule	C_{max}	*F*	*I*	*T*	FF_y	*SR*	*QR*
1	H-MOIA + MIDOS	MIROS	10 14 2 5 3 1 0 4 7 8 9 6 11 12 13	110	601	0	559	265	12	2
2			2 5 14 1 0 4 8 9 3 6 7 10 12 11 13	111	662	0	569	279.5	33	2
3	CSA + MIDOS	MIROS	7 4 2 0 6 5 8 1 11 12 14 3 9 13 10	116	608	11	619	283.5	7	4
4			5 1 3 14 9 2 10 8 4 11 6 0 12 7 13	120	644	19	659	302.3	13	3

4.2 MIROS

The question which arises in such a situation is what happens if the bottleneck fails before the planned maintenance work?. In order to answer the above question, reactive schedules were generated using the MIROS for the best predictive schedules (obtained using the H-MOIA + MIDOS or CSA + MIDOS). Reactive schedules are evaluated using the criteria, solution robustness SR and quality robustness QR [3]. For the assumption that the real MTTF of the bottleneck equals 63, the detailed results achieved for the job shop scheduling problem (15 × 10) using different basic schedules are presented in Table 6.

Taking into account the fitness function of criteria of $C_{\max}$, *F*, *T* and *I*, the basic schedules generated by the MOIA (Tables 1, 2, 3 and 4) are the best input data for

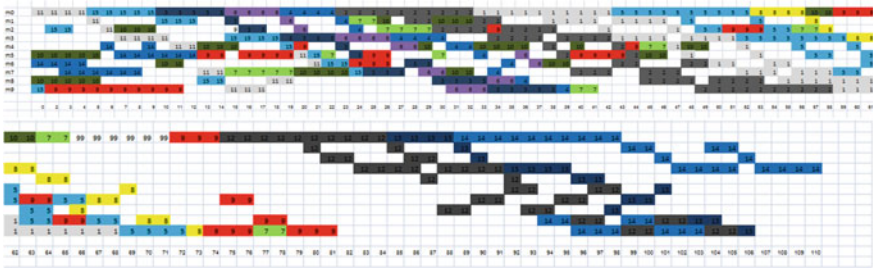

Fig. 1 The best predictive schedule achieved by the H-MOIA

the MIDOS. However, further analysis indicated that the predictive schedules generated by the MIDOS and input data achieved by the MOIA absorb the effect of the bottleneck failure more efficiently taking into account the quality robustness *QR* (Fig. 1). The predictive schedules generated by the SCA + MIDOS are more stable taking into account the solution robustness *SR* (Fig. 1). The best predictive schedule achieved by the H-MOIA is presented in Fig. 1.

5 Conclusion

In the paper two immune algorithms were applied for the basic schedule generation problem for the job shop system: the MOIA and CSA. The MOIA obtains the best performance of the job shop system when the objective is to minimise: makespan, flow time, total tardiness and idle time. Achieved priority schemes encode schedules with no delayed tasks.

The influence of the quality of basic schedules over the quality of predictive and reactive schedules was also investigated. The predictive schedules generated by the SCA + MIDOS are more stable, and the predictive schedules generated by the MOIA + MIDOS are more robust. Although the CSA + MIDOS generates more stable schedules, all schedules are poor quality taking into account the total tardiness criterion.

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Synergetic Models of Customer–Seller Relations

Aleksandr Katkow

Abstract This article is devoted to the problems of computer simulation models of market relations as an example of trade companies. The distinctive feature of economic relations is that they take place in systems that are open systems. The structure of economic relations is subject to constant alterations, which occur during the changing of the relationship between local market participants and especially the micro-level relationships. The micro-level relationships, in view of their goals, cause a change in the structure of market relations at the macro level. For systems based on market relations, the characteristic feature is self-organizing. The paper considers synergetic models based on simulations of market relations at the micro level with the implementation of these relationships on a mass scale in the environment of cellular automata by means of the Lotka-Volterra Prey-Predator model.

Keywords Synergetics · Economic synergetics · Model of market relations

1 Introduction

Economic systems are complex systems due to the multidimensionality of the processes occurring in market relations. These systems are self-organizing. The organizational structure of such systems is hierarchical and based on the realization of market relations at the Customer–Seller level, similar as Lotka-Volterra model describes interactions between two species in an ecosystem, a Prey and a Predator [1]. The paper deals with the relationship between market actors in the commercial sector. The study of the market at the global level starts with the understanding of the main motives of market participants' behavior relations and the possibilities provided by computer simulation modeling techniques. For systems based on market relations, the characteristic feature of the systems is their ability to self-organize. The field of science that investigates the processes that organize

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themselves in complex systems is Synergetics [2–4]. The computing environment best suited for the modeling of market relations is cellular automata [5, 6]. Cellular automata provide a modeling environment consisting of autonomously acting cells. The cells are combined in the spatial calculation structure (two dimensional or three dimensional and more). The cellular automata are implemented in the structure of MIMD (Multiple Instruction Multiple Data) based off of Flynn's model. With a MIMD computing structure in each cell, a local algorithm can be implemented in each cell. The structure of the algorithm depends on the nature of market relations, which are simulated in the cells and the spatial location of a cell in a structure of cellular automata. Therefore it is possible to simulate a Customer–Seller relation that depends on the commercial opportunities of market participants in their relationships and their spatial location.

2 Preliminaries

The subject of this study is the simulation of relationships between Customers and Sellers, depending on their spatial localization, Customer purchasing power and the ability of commercial companies to meet the needs of Customers. The simulation will consider the relationships between Customers and Sellers. First of all, we realize the possibility of market models of chaotic movement of the Customers and Sellers, who are representatives of commercial companies, which are modeled by the local cellular automaton in the simulation environment, such as [7, 8]. During movement in the market, Customers and Sellers enter into relationships involving the acquisition of certain goods by Customers. For the simulation of the exchange of goods and services, working cells representing Sellers are used.

Three types of models for the simulation of market relations are considered. Model A provides the ability for Customers and Sellers to wander in directions chosen at random from the possible options, namely, up, down, left and right. Market relations in this model are limited by the restriction that Customers can only purchase one unit of goods. The Seller behavior algorithm consists of providing one item of goods to the Customers during market relations. In this model of the implementation of market relations, it is assumed that the Seller has an unlimited number of goods. The Customer is considered satisfied if he receives the necessary amount of goods and, afterwards, he disappears from the marketplace. The Seller must sell the goods in some amount of steps, otherwise, he will go bankrupt and disappear from the marketplace. If the Customer does not meet a Seller after the specified number of steps, he initiates the creation of one more Customer. The Seller behavior algorithm in the implementation model A is shown in Fig. 1. In the graph of the Seller behavior algorithm, the relevant position represents the following states:

(a) The state of moving in a random direction.
(b) The state of carrying out the sale.

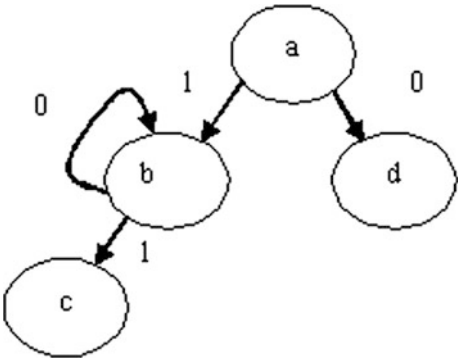

Fig. 1 Seller behavior algorithm for model A

(c) The state of creating a new Seller.
(d) The state of bankruptcy for the Seller and subsequent liquidation of the sales position.

The strategy of each participant in market relations is local, but its execution leads to a steady state in the macro level, which consists of maintaining the exchange of goods and services as a periodic variation of the number of participants in market relations.

If a Customer has not been satisfied after a certain number of steps in the marketplace, then a new Customer in need of goods is created. This new Customer is created in an adjacent cell, which must be free and must be situated in a random direction (up, down, left, right) from the parent cell. After a successful sale of goods to the Customer, the Seller creates a new Seller, which is placed in a free neighboring cell in a random direction. These acts are carried out for the two local strategies corresponding to the behavior of the Customers and Sellers in market relations.

The graph of the algorithm of Customer behavior in model A is shown in Fig. 2.

For the Customer behavior graph algorithm, the corresponding position represents the following states:

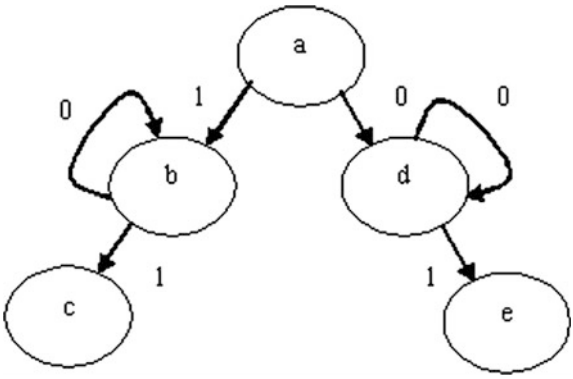

Fig. 2 Customer behavior algorithm for model A

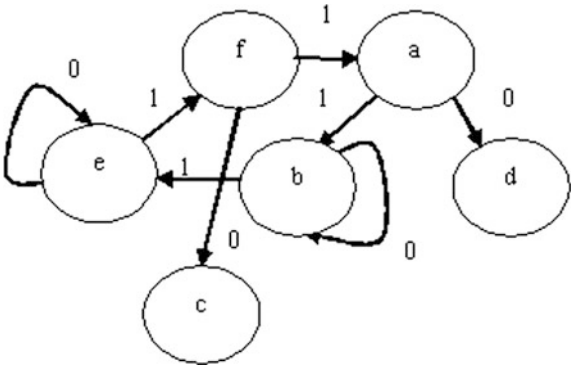

Fig. 3 Seller behavior algorithm for model B

a. The state of moving in a randomly selected direction.
b. The state of purchasing goods.
c. The state of Customer satisfaction and subsequent leaving of the marketplace.
d. The state of searching the goods.
e. The state of creation of a new Customer.

In model B, the implementation of the Customer behavior algorithm does not change compared to model A, but the Seller behavior algorithm does change. In this variant, the Seller has a predetermined limited amount of goods and only after the successful sale of some goods does he have the ability to create a new Seller. The newly created Seller is also created with a predetermined amount of goods. The graph of the Seller behavior algorithm in this variant of model B is shown in Fig. 3. The implementation of model B predicts that after a successful sale, the Seller performs an operation (e) and reduces the number of units of goods belonging to him, then the Seller moves to state (f) and calculates the number of units of the Seller's goods. If the Seller has not yet sold all goods the Seller returns to state (a) and then continues to seek Customers. If the Seller runs out of a stock of goods, he moves to state (c) and creates a new Seller. Such acts in model B introduce two new states in the Seller behavior algorithm compared with the algorithm in model A:

(e) The state of reduction of the number units belonging to the Seller.
(f) The state of calculation of the number units belonging to the Seller (Fig. 4).

In the graph of the Customer behavior algorithm in model C, the corresponding positions denote the following states:

a. The state of moving in a randomly selected direction.
b. The state of purchasing goods.
c. The state of Customer satisfaction and subsequent leaving of the marketplace.
d. The state of searching for goods.
e. The state of creating a new Customer.
f. The state of increasing the amount of goods purchased by the Customer.

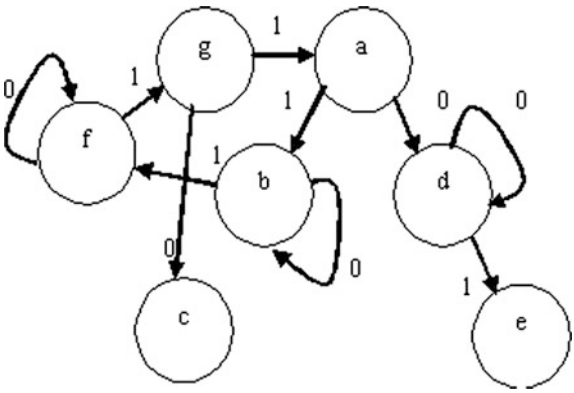

Fig. 4 Customer behavior algorithm for model C

g. The state of verifying the level of the Customer's satisfaction expressed in the quantity of purchased goods.

In state (g), the Customer decides whether to continue moving in the marketplace or to disappear from the marketplace if the Customer is satisfied.

Analyzing the Seller behavior algorithm and the Customer behavior algorithm in model A, B and C it can be concluded that their behavior can be represented by finite deterministic Rabin-Scott (RS) automata. The Rabin-Scott automaton is a special case of the Moore automaton [9]. The Rabin-Scott automaton is an ordered five set

$$A = <X, S, s_0, \delta, F> \quad (1)$$

where: $X = \{x1, x2, \ldots x_n\}$ is a set of symbols (letters) of the input (or the input alphabet), $S = \{s1, s2, \ldots s_n\} \cup \{s0\}$ is a set of internal states with highlighted initial state s0, $\delta: X \times S \rightarrow S$ is a transition function, $F \epsilon S$ is a set of final states. In the present case, the Customer behavior algorithm in model C by RS automata $X = \{0, 1\}$ is the set of input letters, $S = \{a, b, c, d, e, f, g\}$ is the set of internal states with initial state {a}, and $F = \{c, e\}$ is the set of final states. The Customer transition function for model C is presented in Table 1:

Table 1 The transition function of the Rabin-Scott automaton for the Customer behavior

Internal state	Input letters	
	0	1
a	d	b
b	b	f
d	d	e
f	f	g
g	c	a

Table 2 The transition function of the Rabin-Scott automaton representing the Seller behavior

Internal state	Input letters	
	0	1
a	d	b
b	b	e
e	e	f
f	c	a

The Rabin-Scott automaton is said to accept a word x* consisting of input letters if the automaton, after loading the input sequence of letters entering in the word x*, transitions from the initial state {s0} into one of the final states. This can be written in the following way $s_0\delta_{x*} \in F$ where x* is an input word accepted by the automaton. The Rabin-Scott automaton shows that the Customer behavior algorithm of model C accepts the words 10*10*10 and 00*1, where the asterisk character indicates the possibility of multiple readings of the same letter without changing the state automaton. The word 10*10*10 loaded by the RS automaton describes the sequence of states of the Customer behavior algorithm after the successful purchase of goods and the disappearance from the marketplace. The word 00*1 loaded by the RS automaton describes the sequence of states of the Customer behavior algorithm when a new Customer arises. The set of all words accepted by the Rabin-Scott automaton is called a language of the words, accepted by Rabin-Scott automaton. In the case of the presentation of the Seller behavior algorithm in model B by Rabin-Scott automaton, X = {0, 1} is the input set, S = {a, b, c, d, e, f} is the set of internal states with the initial state {a}, F = {c, d} is the set of final states. The Seller transition function for model B is presented in Table 2.

The Rabin-Scott automaton shows that the Seller behavior algorithm of model B accepts the words 10*10*10 and 0. The word 10*10*10 loaded by the RS automaton describes the sequence of states of the Seller behavior algorithm after the successful completion of the transaction of goods and the creation of a new Seller site in the market space. The word 0 loaded by the RS automaton describes the situation of Seller bankruptcy and his disappearance from the market space. These regular expressions can serve as a tool to analyze the behavior of Customers and Sellers in market relations.

3 Computer Simulation

In accordance with the above assumptions the simulation program was developed. The program should perform an interactive modeling of the market, which consists of a certain amount of Customers and Sellers. The main modeling assumptions are as follows.

- Sellers and Customers are able to move in random directions in the marketplace.
- The number of Sellers increases or decreases depending on the amount of goods sold in accordance with algorithms for models A, B and C.
- The number of Customers increases or decreases depending on the amount of goods purchased in accordance with models A, B and C.

The default parameters of the market space are a table of 50 rows and 70 columns and all market space is constructed as an array with dimensions 50 * 70. During the simulation, it is necessary to have the possibility to set the simulation parameters such as the number of Sellers and Customers in an interactive way and to set the type of models of market relations. The implementation of the simulation of market relations is developed using an object-oriented approach.

The following classes of objects are introduced: Marketplace, Seller, Customer, and Cell. Market class objects represent the market as a two-dimensional array of cells. The cells simulate the locations of Sellers and Customers. Their positions in the market place are random. The process of checking the status of each cell on Marketplace is called an iteration. If the Seller and the Customer are located in neighboring cells, they are permitted to enter into market relations. If the Seller turns out to be in a situation where he is surrounded by Customers, he carries out transactions with a random partner in accordance with their ability to sell goods (Model B and Model C) and creates a new Seller. If the Seller turns out to be in the absence of Customers by a predetermined number of steps walking on the market place, he goes bankrupt. During the movement on the market place, the Customer looks for Sellers. After meeting with one of them, he buys goods and disappears from the market space. A Customer who did not buy goods in the marketplace initiates the creation of a new Customer. In Fig. 5, we present the results of the simulation conducted on a model with the following initial parameters: 20 Sellers, 75 Customers, and 110 iterations. The computer simulation in accordance with model A describes the situation of dynamic equilibrium.

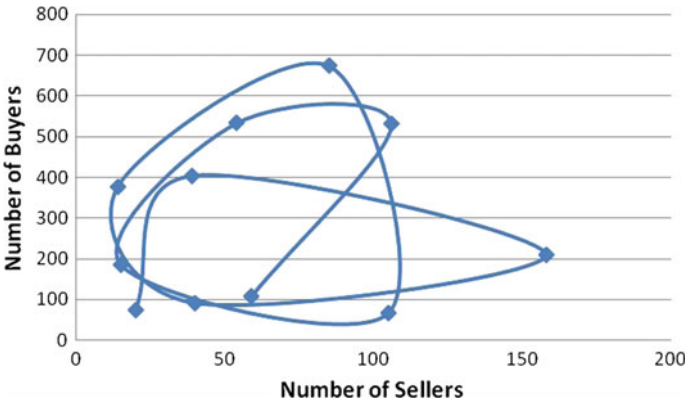

Fig. 5 The results of computer simulation of model A with 110 iterations and 20 Sellers, 75 Customers

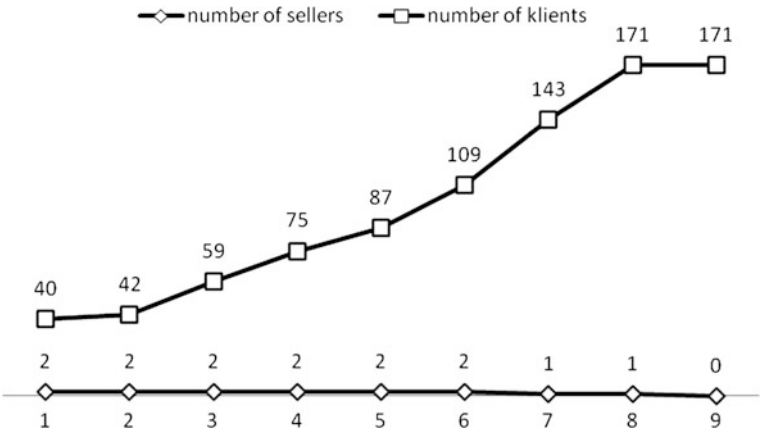

Fig. 6 The results of computer simulation of model A with 90 iterations, 40 Customers, and 2 Sellers

The number of Sellers and Customers is changing cyclically since as the number of Customers increases, the number of Sellers also increases. However, after the market is saturated with goods, the number of Customers falls, causing the bankruptcy of a number of Sellers. Reducing the amount of Sellers causes an increase in demand for goods in the Customer's environment, and causes an increase in the number of Customers (Fig. 6).

The initial values of the simulation process are important for the development of the process.

The simulation results in this case are shown in Fig. 7. An analogous situation takes place for too many initial Sellers. Figure 8 shows the development process

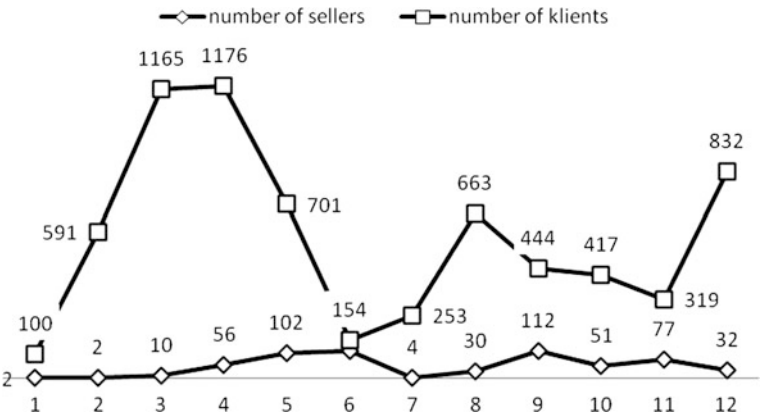

Fig. 7 The results of computer simulation of model A with 120 iterations, 100 Customers, and 2 Sellers

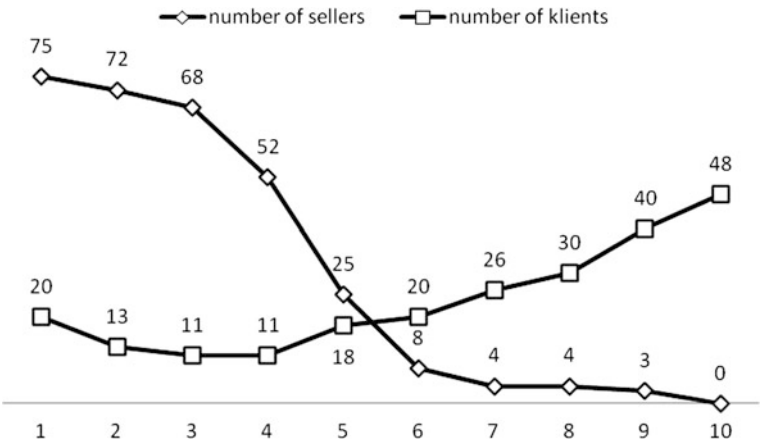

Fig. 8 The results of computer simulation of model A with 100 iterations, 20 Customers, and 75 Sellers

with a high value of the initial amount of Sellers (75) and a small number of Customers (20).

A large number of Sellers and a small number of Customers causes mass bankruptcy of the Sellers and, as a result, leads to the collapse of the whole process after 100 iterations.

4 Summary

This article describes the computer simulation of market relationships using trading companies as an example. The performed research shows the possibility of simulating the relationships between Sellers and Customers by finite automata. These relations can be represented by regular expressions. This article considers models based on simulations of market relations at the micro level with the implementation of these relationships on a mass scale in the environment of cellular automata. With this, it is important that in terms of synergetic can observe and assess the impact on the quality of the organization of the market of its features informal such as the size of the market and its geometric form, the optimal variants of the location of outlets and their number, designation tracks traffic Customers in the environment Sellers and others, which is very hard and elsewhere impossible to determine formally using mathematical apparatus.

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Exponential Inertia Weight in Particle Swarm Optimization

Bożena Borowska

Abstract This paper presents an improved particle swarm optimization algorithm (EWPSO) with a novel strategy for inertia weight. In the new algorithm, nonlinear inertia weight is proposed. The new weight is an exponential function of the minimal and maximal fitness of the particles in each iteration. The set of benchmark function was used to test the new method. The results were compared with those obtained through the standard PSO with linear decreasing inertia weight (LDW-PSO) and RNW-PSO. Simulation results showed that EWPSO is more effective for the tested problems than both LDW-PSO and RNW-PSO.

Keywords Optimization · Particle swarm optimization · Inertia weight

1 Introduction

Particle swarm optimization (PSO) is a population based search algorithm introduced by Kennedy and Eberhart in 1995 [1, 2]. It belongs to the category of algorithms inspired by observations of natural, social behavior occurring in the systems of different organisms. Because of its easy implementation and low computational costs, it has been applied for solving different, complex optimization problems [3–9]. One of the crucial parameters that affect the PSO performance is inertia weight. Its value determines the impact of the speed used in the previous iteration to the current speed of the particles. Inertia weight provides a balance between global and local explorations. A large inertia weight facilitates global exploration while a smaller one tends to facilitate local exploitation [10–12]. Many papers propose adjustment of the inertia weight factor by means of which the performance of PSO can be improved [13, 14].

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Instead of a fixed inertia weight, Eberhart and Shi [10] introduced a linear decreasing inertia weight. Zhang et al. [15] considered random inertia weight uniformly distributed in [0, 1]. Performance of the PSO with flexible inertial weight parameter that can be either a negative real number or positive one was examined by Han et al. [16]. Depending on the value of the coefficient w, the authors used two different update equations of particle velocity. Jiao et al. [17] proposed IPSO, which uses the dynamic inertia weight that decreases according to iterative generation increasing. Dynamically modified inertia weight was also applied by Yang et al. [18]. However, in this case, the inertia weight is different for each particle of swarm and is given by a function of evolution speed factor and aggregation degree factor. Another method to dynamically adjust the inertia weight by dispersion degree and advance degree factors was introduced by Miao et al. [19]. Three new weight strategies with using Gompertz function were develop by Chauhan et al. [20]. For dynamic adaptation of inertia weight, Shi and Eberhart [21] applied the elements of fuzzy logic. According to the authors, modification of inertia weight based on fuzzy system can significantly improve the efficiency of the algorithm. The use of fuzzy logic to determine the value of inertia weight can also be found in [22–26].

This paper presents a novel strategy for inertia weight to improve the performance of the algorithm. Instead of linear inertia weight (applied in many articles) exponential weight has been introduced. The new weight is a function of the minimal and maximal fitness of the particles. The new algorithm was tested with a set of benchmark functions [27, 28] and the results were compared with those obtained through the standard PSO with linear decreasing weight (LDW-PSO) and PSO with a random number inertia weight (RNW-PSO) method proposed by Zhang et al. [15].

2 The Standard PSO

In the standard PSO, the optimization is performed by a population of particles named a swarm. Each particle of the swarm has its individual location x_i and velocity v_i that are randomly generated when the algorithm starts. In an D-dimensional search space, the particle is represented by vectors $X_i = (x_{i1}, x_{i2}, \ldots, x_{iD})$ and $V_i = (v_{i1}, v_{i2}, \ldots, v_{iD})$.

At each time-step, the positions and velocities of the particles are adjusted and then fitness of the particles with their new updated coordinates is evaluated. Evaluation is performed according to the objective function of the optimization problem. In each step of the algorithm, each particle remembers its personal best position (named *pbest*) found so far and the best position among all the particles in the whole swarm (named *gbest*) is recorded. In every iteration, the velocity and position updating rule is established according to the formula:

$$V_i = wV_i + c_1 r_1 (pbest_i - X_i) + c_2 r_2 (gbest - X_i) \quad (1)$$

$$X_i = X_i + V_i \quad (2)$$

where w is the inertia weight. A larger inertia weight tends to facilitate global exploration whereas a smaller inertia weight facilitates local exploration [17]. The variables c_1 and c_2 are acceleration constants that determine how strong the particles are influenced by pbest and gbest, r_1 and r_2 are used to maintain diversity of the population and represent randomly generated numbers in the range (0, 1).

3 The Proposed EWPSO Algorithm

In the presented EWPSO algorithm, the particle swarm optimization with a novel, effective strategy for selecting inertia weight is proposed. It is a nonlinear, dynamic strategy. The novelty of the approach relies on introducing a new method for calculating inertia weight based on particles performance. In each iteration, particles with the best and the worst fitness are selected and, on the basis of their fitness, the new inertia weight is calculated. The new weight is an exponential function of the minimal and maximal fitness of the particles. A different inertia weight is counted for the whole swarm in each iteration. This strategy can be described according to the following formula:

$$eiw = (f_{\max} - f_{\min}) e^{-fh} / 1000 fb f_{\max} \quad (3)$$

$$w(t+1) = w(t) - eiw(t) \quad (4)$$

where f_{max} and f_{min} are the values of maximal and minimal fitness in the current iteration, respectively. Factor fh is randomly generated number in the range [0, 1], fb determines how much the inertia weight is influenced by maximal fitness and is uniformly distributed in [0, 1]. In this way, EWPSO algorithm can considerably improve the performance of the PSO with low computational cost.

4 Results

The impact of the proposed inertia weight on the PSO performance was tested with a set of benchmark function taken from the literature. The information about the functions is depicted in Table 1. The results of the simulations are compared with

Table 1 Optimization test functions

Function	Formula	Minimum	Range of x
Sphere	$f_1 = \sum_{i=1}^{n} x_i^2$	0	(−100, 100)
Rosenbrock	$f_3 = \sum_{i=1}^{n-1} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2$	0	(−30, 30)
Ackley	$f_4 = -20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}\right) - \exp\left(\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)\right) + 20 + e$	0	(−32, 32)
Rastrigin	$f_5 = \sum_{i=1}^{n}(x_i^2 - 10\cos(2\pi x_i) + 10)$	0	(−5.12, 5.12)
Griewank	$f_6 = \frac{1}{4000}\sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n}\cos\left(\frac{x_i}{\sqrt{i}}\right) + 1$	0	(−600, 600)

the performance of PSO with linear decreasing weight (LDW-PSO) as well as RNW-PSO with a random number inertia weight.

For all the functions, the investigation with three different dimension sizes D = 10, 20 and 30, for N = 20, 40 and 80 particles in the swarm, respectively, was conducted. The maximum number of iterations was set at 1000 for all the algorithms. The algorithms started with inertia weight w = 0.6 and acceleration constants c1 = 1.7 and c2 = 1.7.

The exemplary results (mean function value, minimum and standard deviation) of the tests performed for 20, 40 and 80 particles of the swarm are illustrated in Tables 2, 3, 4 and 5. The presented values were averaged over 50 trials.

Table 2 Performance of the LDW-PSO, RNW-PSO and EWPSO algorithms for Rosenbrock function

Population size	Dimension	Algorithm	LDW-PSO	RNW-PSO	EWPSO
20	10	Mean	4.1791e+001	1.6804e+001	1.3776e+001
		St. Dev.	2.4788e+001	2.2812e+001	2.2688e+001
		Min	4.7219e+000	7.7738e−001	2.1808e−001
	20	Mean	8.2532e+001	2.2173e+002	7.1994e+001
		St. Dev.	4.6017e+001	3.0739e+002	1.0079e+002
		Min	1.4925e+001	1.5612e+001	8.8499e−001
	30	Mean	1.3893e+002	4.3562e+002	1.6929e+002
		St. Dev.	1.6827e+002	5.6524e+002	1.4744e+002
		Min	2.1633e+001	3.1382e+001	1.9885e+001
40	10	Mean	2.4095e+001	1.7636e+001	4.2446e+000
		St. Dev.	1.6334e+001	3.0743e+001	5.4232e+000
		Min	3.7411e−003	1.1275e+000	1.6397e−002
	20	Mean	5.5692e+001	5.2173e+001	4.4838e+001
		St. Dev.	5.4176e+001	4.5001e+001	4.5547e+001
		Min	5.8804e+000	5.2141e+000	2.1175e+000
	30	Mean	7.2285e+001	7.1375e+001	6.7793e+001
		St. Dev.	1.4720e+002	3.2906e+001	7.7249e+001
		Min	1.0631e+001	1.0344e+001	7.0879e+000
80	10	Mean	1.7436e+001	1.6993e+001	1.1882e+001
		St. Dev.	3.1489e+001	2.0098e+001	2.1335e+001
		Min	1.1755e−001	3.1669e−003	9.0311e−003
	20	Mean	4.6463e+001	3.1023e+001	2.1994e+001
		St. Dev.	3.5278e+001	2.5074e+001	2.6712e+001
		Min	1.3024e−001	5.5702e−001	1.6356e−005
	30	Mean	6.5990e+001	3.9974e+001	3.8189e+001
		St. Dev.	1.2902e+002	2.8443e+001	2.4981e+001
		Min	8.0705e−001	1.3821e+001	1.3507e+001

Table 3 Performance of the LDW-PSO, RNW-PSO and EWPSO algorithms for Rastrigin function

Population size	Dimension	Algorithm	LDW-PSO	RNW-PSO	EWPSO
20	10	Mean	6.3407e+000	6.2914e+000	6.0946e+000
		St. Dev.	4.3979e+000	7.0143e+000	4.1591e+000
		Min	3.2156e+000	2.9798e+000	9.9496e−001
	20	Mean	4.2839e+001	5.3967e+001	4.3542e+001
		St. Dev.	1.5097e+001	1.7657e+001	1.3172e+001
		Min	2.2407e+001	3.3829e+001	2.5869e+001
	30	Mean	7.9012e+001	8.8321e+001	8.3054e+001
		St. Dev.	2.1957e+001	2.8082e+001	2.4179e+001
		Min	4.4655e+001	6.1914e+001	3.6821e+001
40	10	Mean	4.3174e+000	4.2738e+000	4.0964e+000
		St. Dev.	4.0391e+000	1.9138e+000	3.5946e+000
		Min	9.8907e−001	2.9849e+000	9.9496e−001
	20	Mean	2.3784e+001	2.4227e+001	2.0923e+001
		St. Dev.	1.0752e+001	9.4191e+000	1.0951e+001
		Min	1.1628e+001	1.4924e+001	1.8904e+001
	30	Mean	7.2551e+001	7.1438e+001	6.7707e+001
		St. Dev.	3.1420e+001	1.8540e+001	2.2216e+001
		Min	3.7293e+001	4.2783e+001	3.6813e+001
80	10	Mean	2.5044e+000	2.5077e+000	2.3311e+000
		St. Dev.	4.3115e+000	3.0385e+000	1.5097e+000
		Min	9.7605e−001	9.9496e−001	9.9496e−001
	20	Mean	3.1027e+001	3.0893e+001	2.7511e+001
		St. Dev.	9.5914e+000	9.2914e+000	1.1382e+001
		Min	1.4163e+001	1.7909e+001	1.0939e+001
	30	Mean	5.5134e+001	5.4225e+001	5.4009e+001
		St. Dev.	1.6283e+001	1.7274e+001	1.5998e+001
		Min	4.3807e+001	3.0844e+001	3.6813e+001

The average best fitness in the following iterations for both EWPSO, RNW-PSO algorithms and LDW-PSO model for 40 particles (swarm size) and 30 dimensions is illustrated in Figs. 1, 2, 3 and 4. The vertical coordinates indicate the average best fitness in the form of logarithm value.

The results of experiments confirmed that EWPSO is more effective for the tested problems than LDW-PSO and RNW-PSO. For all the tested functions, in all cases (except tests with swarm size of N = 20 particles and with dimension D = 30 and except tests for Rastrigin and Sphere function with swarm size N = 20 and

Table 4 Performance of the LDW-PSO, RNW-PSO and EWPSO algorithms for Ackley function

Population size	Dimension	Algorithm	LDW-PSO	RNW-PSO	EWPSO
20	10	Mean	3.3109e−001	1.1964e−000	3.1295e−001
		St. Dev.	6.4035e−001	1.2397e−000	5.5799e−001
		Min	3.9968e−015	3.8989e−14	3.9968e−015
	20	Mean	4.5018e+000	4.4621e+000	2.3925e+000
		St. Dev.	1.5372e+000	1.4145e+001	1.9893e+000
		Min	9.7149e−012	2.6997e+000	4.9457e−009
	30	Mean	7.8902e+000	7.4163e+000	5.1852e+000
		St. Dev.	1.6513e+000	2.2702e+000	2.7345e+000
		Min	2.5014e+000	4.0363e+000	1.1551e+000
40	10	Mean	4.4172e−012	3.9968e−015	3.9968e−015
		St. Dev.	1.4338e−012	00000e−000	0.0000e−000
		Min	3.9968e−015	3.9968e−015	3.9968e−015
	20	Mean	9.3837e−001	9.1282e−001	6.6614e−001
		St. Dev.	8.9104e−001	8.7925e−001	7.9908e−001
		Min	4.3256e−015	1.0720e−003	3.7906e−015
	30	Mean	6.7141e+000	5.6425e+000	2.6836e+000
		St. Dev.	9.2031e−001	1.9480e+000	1.3052e+000
		Min	1.2052e+000	1.3283e+000	1.1551e+000
80	10	Mean	4.2319e−014	3.9968e−015	3.8192e−015
		St. Dev.	1.6173e−014	00000e−000	7.9441e−016
		Min	3.7989e−015	3.9968e−015	4.4408e−016
	20	Mean	2.1543e−001	2.1310e−001	1.4976e−001
		St. Dev.	4.7414e−001	5.1659e−001	4.3811e−001
		Min	3.9968e−015	7.5495e−015	3.9968e−015
	30	Mean	1.3014e+000	1.1743e+000	4.3377e−001
		St. Dev.	1.1732e+000	1.1791e+000	7.7965e−001
		Min	3.1799e−014	1.4654e−014	7.5495e−015

dimension D = 20) the mean function values, after 1000 iterations, found by EWPSO were lower (better) than the findings obtained by the remaining algorithms. For Sphere, Ackley and Griewank functions, the standard deviation and minimum value were also lower than the ones achieved by RNW-PSO and LDW-PSO what indicates that EWPSO for this function is more stable than the others. For Rastrigin and Rosenbrock functions, in almost all cases, the algorithm was more stable than LDW-PSO but less stable than in case of RNW-PSO, and the minimum value was not always the best (the lowest) one. In all tests, the new algorithm converged faster

Table 5 Performance of the LDW-PSO, RNW-PSO and EWPSO algorithms for Griewank function

Population size	Dimension	Algorithm	LDW-PSO	RNW-PSO	EWPSO
20	10	Mean value	9.5273e−002	1.0284e−001	8.0590e−002
		St. Dev.	8.1844e−002	4.0914e−002	3.7090e−002
		Min	1.4761e−002	3.4477e−002	1.2316e−002
	20	Mean value	5.9908e−002	5.7156e−002	2.2468e−002
		St. Dev.	6.3084e−002	3.9125e−002	2.5224e−002
		Min	1.1205e−004	00000e+000	00000e+000
	30	Mean value	1.7918e−001	3.8119e−000	1.8215e−001
		St. Dev.	2.6779e−001	3.8371e−000	2.8747e−001
		Min	3.0105e−009	1.1223e−001	6.1233e−006
40	10	Mean value	7.7242e−002	7.2329e−002	6.8275e−002
		St. Dev.	6.3084e−002	4.1961e−002	1.3524e−002
		Min	5.4519e−003	6.1504e−002	1.7236e−002
	20	Mean value	5.2607e−002	4.3211e−002	4.0159e−002
		St. Dev.	5.0821e−002	3.1522e−002	2.9501e−002
		Min	9.7415e−004	00000e+000	0.0000e+000
	30	Mean value	3.4165e−002	3.2036e−002	2.4962e−002
		St. Dev.	4.2482e−002	3.9266e−002	3.8662e−002
		Min	6.5067e−003	9.8573e−003	3.1308e−014
80	10	Mean value	6.8004e−002	6.3636e−002	5.8541e−002
		St. Dev.	3.6143e−002	5.4708e−002	2.7337e−002
		Min	5.2441e−003	3.6931e−002	7.3960e−004
	20	Mean value	2.8657e−002	2.4246e−002	2.0164e−002
		St. Dev.	1.5339e−002	1.9321e−002	1.4635e−002
		Min	0.0000e+000	00000e+000	0.0000e+000
	30	Mean value	1.9084e−002	1.4917e−002	9.3564e−003
		St. Dev.	1.5430e−002	1.7167e−002	1.5297e−002
		Min	0.0000e+000	00000e+000	0.0000e+000

than LDW-PSO and RNW-PSO as shown in Figs. 1 and 4. In case of Rastrigin and Griewank functions, initially the RNW-PSO algorithm was a bit faster than EWPSO (Figs. 2 and 4) but after about 100 iterations (in case of Rastrigin) and about 300 iterations (in case of Griewank function) the EWPSO converged faster than RNW-PSO and LDW-PSO. RNW-PSO algorithm converged slower than EWPSO but still better than LDW-PSO.

It should be added that when the number of particles in the swarm was increased, EWPSO algorithm converged faster and obtained solutions of better quality.

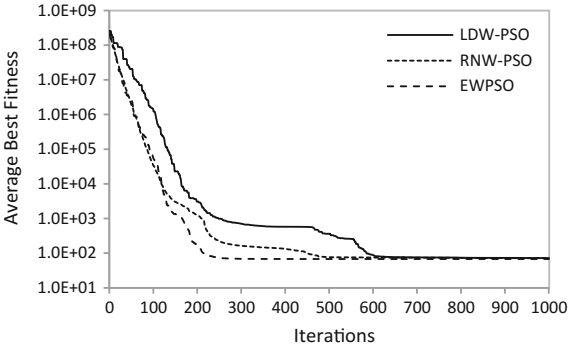

Fig. 1 The average best fitness for Rosenbrock 30 and the population of 40 particles

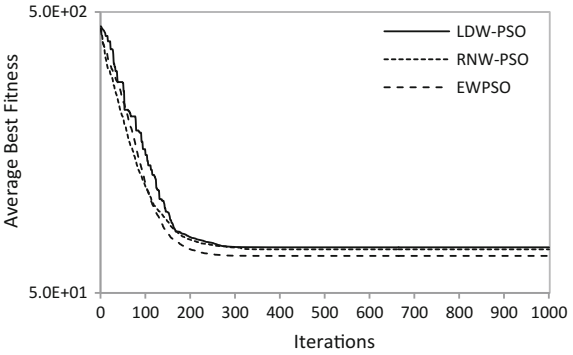

Fig. 2 The average best fitness for Rastrigin 30 and the population of 40 particles

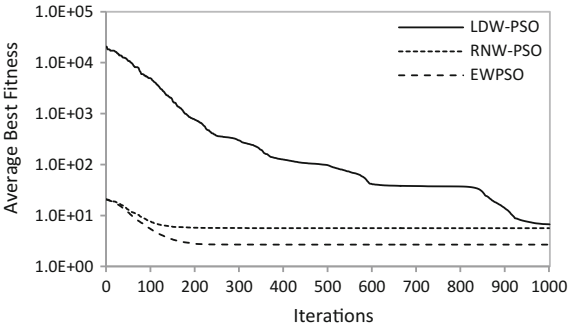

Fig. 3 The average best fitness for Ackley 30 and the population of 40 particles

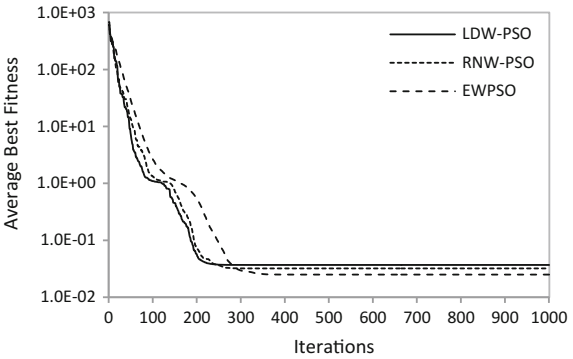

Fig. 4 The average best fitness for Griewank 30 and the population of 40 particles

5 Summary

In this paper, an improved particle swarm optimization algorithm called EWPSO with a novel strategy for inertia weight has been proposed. The new weight is an exponential function of the best and the worst fitness of the particles.

The new algorithm was tested with a set of benchmark functions. The results of the investigations were compared with those obtained through PSO with linear decreasing weight (LDW-PSO) and RNW-PSO with random inertia weight. The use of proposed, exponential inertia weight considerably improved algorithm performance. The new algorithm was faster and more effective over LDW-PSO and RNW-PSO in almost all cases. Furthermore, the proposed algorithm had greater convergence rate compared to other algorithms.

The best results were obtained for 40 and 80 particles in the swarm. In cases of too small swarm size and too high dimension of the search space (N = 20, D = 20 and 30), the solution quality deteriorated and the risk of premature convergence to non-optimal points was increasing.

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Marketing Model of Value Creation (4V's Model of the Product)

Grzegorz Cieloch

Abstract The key issue of the paper is a synthesis of different marketing models into one consistent idea. It should allow to show how the value for the customer is created and how to analyze it on the model. The work starts from generic strategies model, which was developed in strategy clock. A map of product value is the main result. Resulted model is confronted with some existing models and tested on 2 case studies.

Keywords Marketing management · Product model · Value of the product · Value for customer · Strategy clock · Generic strategies

1 Introduction

The aim of this paper is to integrate product models defined in different marketing concepts into a single frame. This frame implies at least the theoretical possibility of measuring the value of the product. Admittedly, existing marketing concepts contain information about the value of the product, but the criteria by which you can create and assess the product value still remain undefined. In marketing the price is not a measure of the product value, as it makes a different marketing tool. Neither does it measure the production cost, because the buyer usually does not know the costs and is not interested in it. The consistency of marketing ideas and the very definition of a product require further studies on models of a product which provide conditions for value assessment.

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2 Strategy Clock of Johnson and Scholes as a Starting Point for the Map of Values

This strategy model is a very useful tool that helps to show the essence of the process during which the product value is created for the customer. In marketing two meanings of the value concept are used. The first, referred to the goodwill is a measure of the result: efficiency and effectiveness of marketing strategy. The second, understood as the value for the customer, is a proposal, an offer which has to be accepted by the market. The concept of increasing the goodwill by marketing activities creates a distinct trend in thinking about marketing, which gives to this marketing concept a chance to make the interest of companies' management more reliable. So far marketing more often than not was placed as the costs' center than profit center, the approach which also runs through the work of Doyle [1]. The work of this author is devoted mainly to the problem of increasing the value of the company. The author defines it as the sum of the total discounted net cash flows generated by the company. The sum, in the given unit of time, is the number of products sold multiplied by prices of each sale reduced by expenses and investment. In order to optimize this objective, the lower and upper limit of price variability should be well recognized by the company. While the lower limit is relatively easy to determine, as it is based on the elements controlled by the company, the upper limit is determined by the product value for the buyer. In the literature it the notion of the value of the product to the buyer is discussed. Paper by Chlipala [2] contains an interesting overview of the publications on that issue. The authors quoted there point out at the value creating role of relationship and the process of increasing the product value in relationship marketing. The dangerous temptation of relationship marketing is, however, treating the customer as the asset of the company and the whole concept of CLV (Customer Lifetime Value) [3]. This concept is fully justified as company management goal. However, the creation of the product value is not about the customer as a value, but the value for the customer. This means that the relations should bring additional benefits to the customer.

The tool known as Johnson and Scholes as the strategy clock is based on two concepts: a price and a perceived value of the product. Johnson and Scholes consider the strategy clock a better, more advanced solution than M.E. Porter's [4, 5] the generic strategy matrix (Fig. 1).

The significance of the strategy clock concept is its potential to consider perceived product values against their prices. According to the authors quoted, the price is a payment for the benefits offered by product, and the transaction is a positive verification of the offer.

To keep things clear, we'll explain the strategies with respective numbers:

1—a strategy of low expectations regarding the benefits and low price as an offer selection criterion; such situation often occurs in the market run by governmental, self-governmental auctions and budgetary units; and in open markets it can be found in those segments where buyers are very price sensitive,

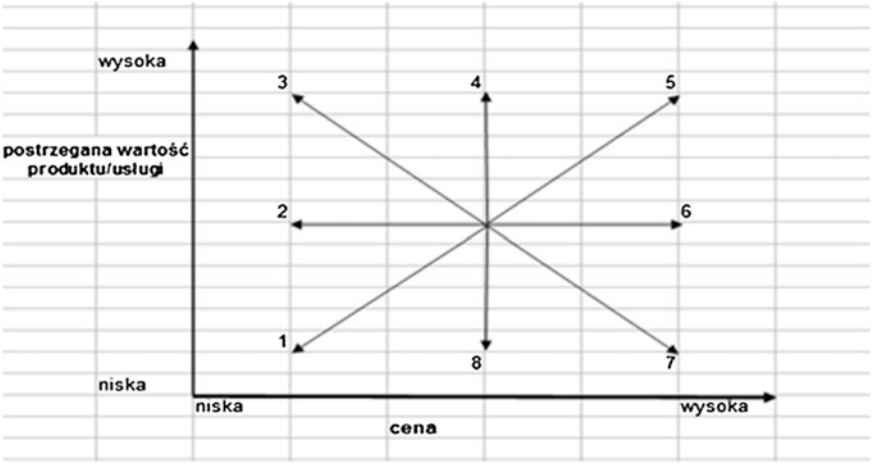

Fig. 1 Strategy clock (*Source* Johnson et al. [5], p. 225.)

2—average perceived value for a low price in practice is no more than only slightly modified strategy № 1. Both strategies considered from the supply side of the market appear to be short lasting, their probability of the development in the market is also low,

4—differentiation strategy: a high perceived value for medium price is usually addressed to multiple market segments, here the products purchased by price sensitive buyers are offered,

3—hybrid strategy based on the simultaneous achievement of differentiation and price advantage—in Europe IKEA has developed such market strategy. Here differentiation, which is a particular value for the customer, is achieved without increase increasing the expenses. The whole point of this strategy is to achieve a high sales volume which makes up for a relatively low profit margin presumably lower than the average one. Hybrid strategy is also typical strategy of entering new markets already serviced by the competitors,

5—this strategy, targeted at market segments with high requirements and large financial resources is, like strategy 3, a modification of strategy 4. It is also the result of a conscious choice of the segment which is smaller, but provides the probability of achieving a high unit margin. In this strategy the adaptation of the offer to the requirements of a chosen market segment is the condition of success,

6, 7, 8—are defined as failure strategies Here too low values are offered for a high or medium price.

The companies appearing on the supply side are free to choose product policies, i.e., policy of the benefits provided by the product and policy of prices. Buyers can accept or reject any particular value-pricing offer.

The volume or value of transactions concluded under given conditions indicates the adequacy of adopted strategy.

The conclusions of the clock strategy are following:

- the price and value of the product cannot be regarded as identical concepts,
- the buyer compares the price with the value and having considered it takes a decision about purchase,
- for the buyer value can be purely subjective, even personal concept,
- for the company product value is, just like the price, one of the elements of strategic choice, that is why the company should have the concept of creating value for the customer, know what product components create its value, and strive for full control of the value creating process especially by measuring each component's value.

This paper is an attempt of meeting such a need of the company.

- The rule of the buyer's rationality

Looking at the clock strategy from the buyer's perspective, we are be able to deduce the principle of rational choice made by the buyer. Buyers optimize their choice, if the product price does not exceed the perceived value. Depending on his spending power and value preferences the buyers can:

- minimize the purchase price keeping the given value of product, or
- optimize or maximize the benefit without exceeding the accepted financial limits.

In extreme cases, when the product price is relatively low in comparison with the assets available for the buyer, he can maximize the benefit (the product value) without an established price limit.

However, a selective choice is the most common, here the individual components of the value are analyzed and those that meet the needs of the buyer chosen. The less important factors are excluded. Only the benefits which are considered important will be compared with the price.

In this paper we do not discuss the issue of the price determining. It should only be noted that this problem, within the framework defined by the company pricing policy, is relatively easy to solve, and there is a number of tools which help to achieve satisfactory results [6]. Creating the product value is a completely different aspect of the problem.

3 The Essence of the Product Value Map

Many definitions of the product describe it is a set of benefits, the value for the buyer. From the creators of this concept we should expect guidance on how these values are formed. The most common marketing model of product by Ph. Kotler is not suitable for any kind of value analysis or product design [4, 7]. Kotler's model does not refer to the concept of value, whereas in the context of presented company strategic choices "value" makes a key concept.

The model shown above connects four basic components of the product with the process of value creation. Four given dots form the picture of any product value: each dot is located in a separate quadrant of the area. Each of them can be placed anywhere in the quarter and each binds expenses resulting in the unit cost of the product, with the result achieved meant as an increase of a particular component of perceived value (Fig. 2).

Not every investment aimed at the increase of the value of a particular component, influence the unit product cost in a similar way. The unit cost is important, because it sets the lower limits of the permissible price range. Not every money invested in increasing the product component value enhances perceived value in the same way. It is caused by various requirements of individual market segments, the ability of the company to identify the expectations of the customers and meet their needs in a proper, effective way. That, what we mean is the value perceived by the customer. This category is rather impossible to quantify. To determine it qualitative researches and comparisons of the features of the products competing among the strategic group are needed (Fig. 3).

The value of the product is gained effectively, when achieving a high perceived value of the product is accompanied by low increase of the unit cost. The company can implement the strategy № 4, or even 3, if price premium has been given up. Once the lower limit of the price range is set low, the company is able to achieve a profit even it is competing on price.

The value creating process is ineffective, when the high increase of the unit costs results in a small value enhancement. In this case, the lower price limit is high, and

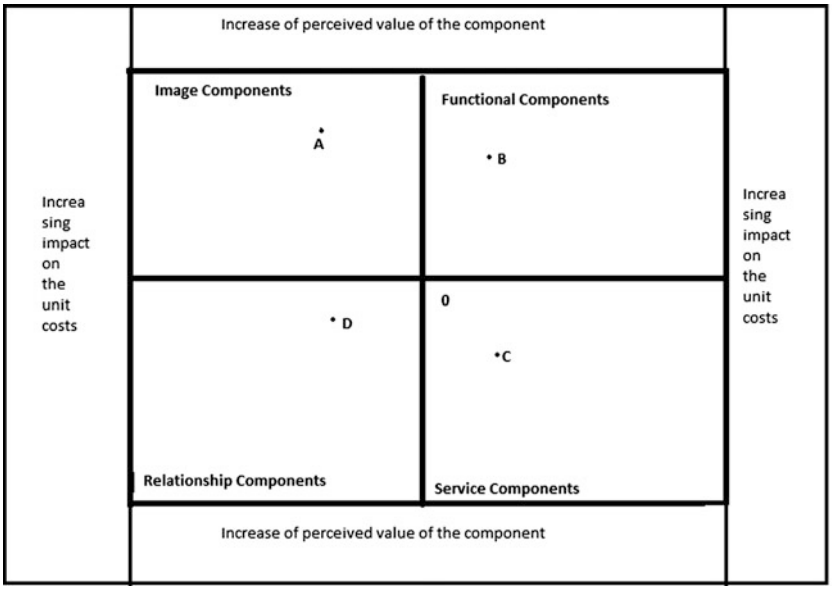

Fig. 2 The product value map, basic version

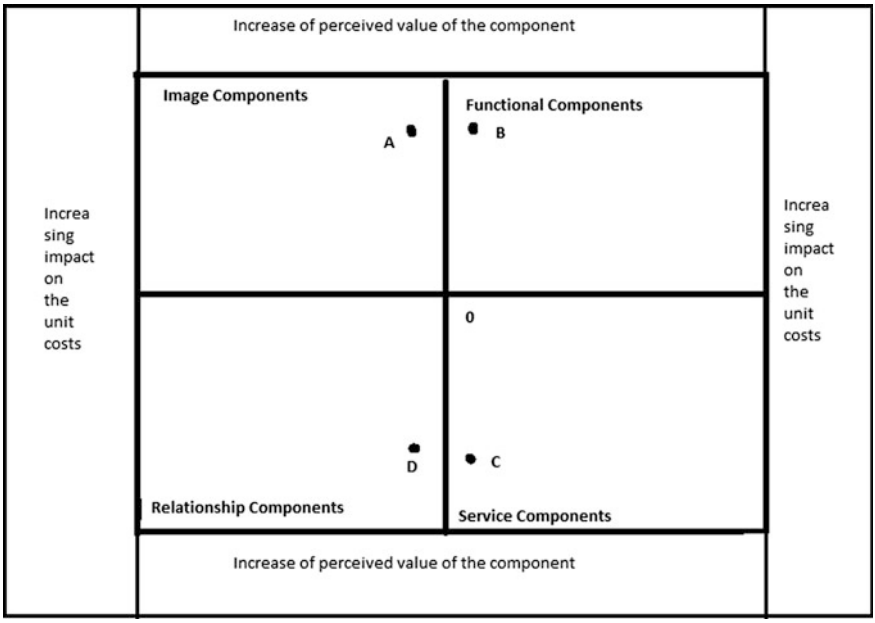

Fig. 3 The product value map of the low impact of sources of value on the unit cost

the likelihood of keeping a high profit per unit decreases. The company can pursue the strategy № 5, if it finds a market segment with specific needs, or the hardly promising strategy № 6.

Referring to picture of the value map we can see that each quarter reflecting the product component needs the third dimension, which illustrates the specific operations, procedures and functions of value creating. The first quarter of the figure refers to the components of the company image. Its detailed list of them is open, but usually we find there all the features that distinguish the product positively: the brand image, packaging and other elements related to the product (but not to other marketing tools).

Vertical and horizontal axes of the value graph can and should have a scale of values. On the horizontal axis we have the unit costs of the product in absolute terms (in monetary units)—or in relative terms (in relation to the basic version of the product costs). On the vertical axis we define the value of the product. It would be difficult to measure the value in absolute terms, still the impact of a single component, belonging to a particular group, can compared to directly competitive products, e.g. a hotel with self-service reception should be cheaper than a hotel of the same category with normal level of service. At this we put aside other value components: branding (e.g. brand value), functional (e.g. location) or relationship (e.g. discounts for a constant customer).

4 Products and Services on the Value Map

Is the matter of discussion if the presented model can be applied equally to material products and services. Here, the classifications of the products by Payne [8] and Kotler [7] are worth recalling. Both authors distinguish two extreme types: material product with no services included and pure service. Between them A. Payne puts a continuum of services, and Ph. Kotler puts only two sets: a material asset plus service with the dominant role of one or the other component.

The product in the form of a material asset only, without any of service, does not have the service value component and, consequently, the relationship component. Its picture on the model is created by two dots on the upper quadrants of the graph.

Pure service, despite the lack of material component, should be pictured on all the quadrants of the graph. There are not many pure services in the market, one of them is learning a foreign language with the native speaker. The work of such person, as we know, is teaching someone a language, which is the mother tongue for the teacher. A functional component of this service may have many dimensions: e.g. the ability to hold a spontaneous conversation on any subject, his or her general education, and knowledge of the living language structures. The image component, apart from physical and mental qualities of the teacher, is also their better or worse opinion. Among the service components we can find the level of customer service, e.g. providing suitable learning conditions. The relationship components can be illustrated by the successful timing of the learning process or the imaginative choice of the topics of conversations with students. The service is personalized by this relationship.

5 Package of the Product on the Value Map

The package makes a very interesting picture on the product value map. It is the component that can create value in each quadrant of the model (Fig. 4).

6 Analysis of the IKEA Product Value

According to Johnson and Scholes IKEA implements the strategy № 3, which is based on providing particular values for customers while maintaining the price advantage [5]. In the Polish market there are a few companies offering furniture at low prices. Bodzio and Jysk certainly belong to this group.

These companies differ significantly from IKEA:

- they offer narrower assortment,
- their stores are much smaller,
- no accompanying services, such as restaurant, food shop, children's playground,

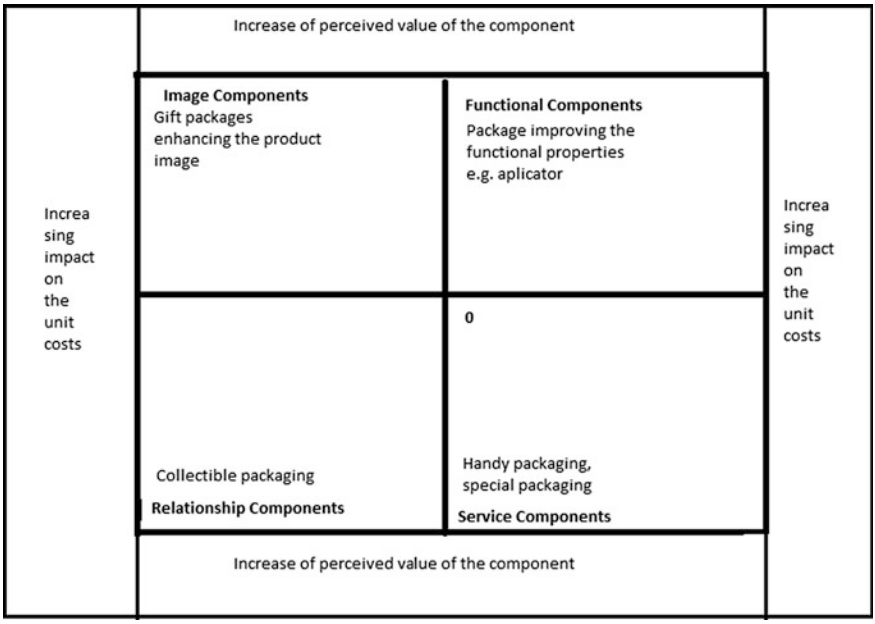

Fig. 4 Package of the product on the value map

- no completely arranged interiors on display,
- no annual catalogues available,
- no individually designed product ranges signed by designers.

A common feature of the three companies is the use of cheap materials, a large range of self-service during the buying process is based mostly on self-service, and —partly—the opportunity to buy packed furniture for self-montage is offered.

However, components forming a particular value for the customer and those which create a cost advantage stem from this short list of differences (Fig. 5).

The source of cost advantage for IKEA are:

- functional components of the product represented by cheap materials and other sources of low production costs,
- the store is self-serviced.

The source of value for the customer are:

- image components represented by the easily recognizable design, "swedishness" of supplementary offer and a popular brand,
- service components: a restaurant (offering meals sold at a profit) and a playground for children; in this case the restaurant improves the service level of the store and enhances the image without increasing unit costs,
- functional components: almost 100-percent availability of the offer in the warehouse.

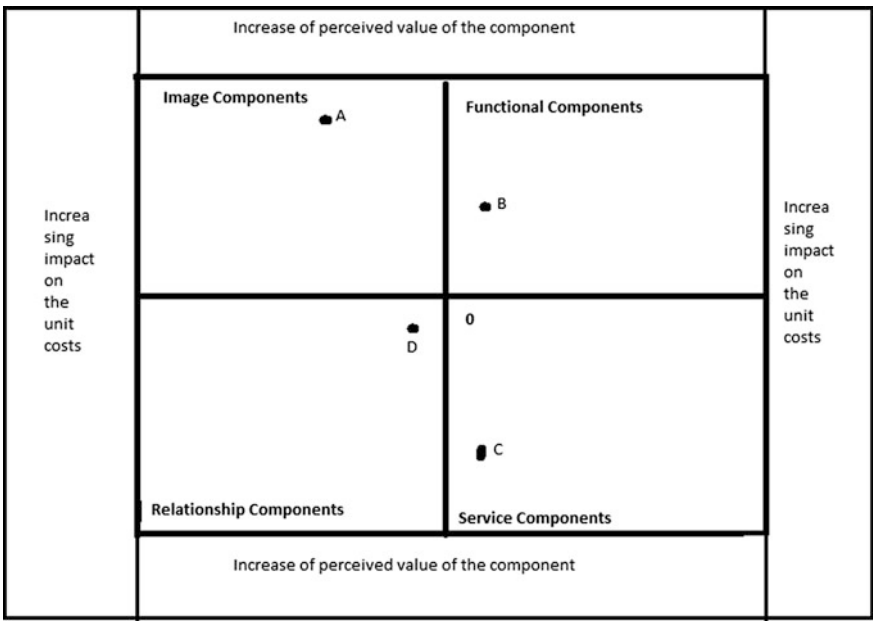

Fig. 5 Picture of the IKEA product on the value map

The underdeveloped relationship component is striking.

High value of the product brand component is achieved by actions only slightly affecting the increase of unit costs. At least average value of functional component is has also been achieved without significant increase of the unit cost. The third component, the service value of the IKEA products also does not affect strongly the unit costs, as additional services are charged, and yet give the customers a sense of comfort. Relationship component of this company is not important and does not affect the expenses.

7 Monad, Molecule and Sequence on the Value Map

Apart from the product model developed by Ph. Kotler and lot of its repetitions and modifications, a concept by Rogozinski [9] is known in Poland. It distinguishes three types of the product: Monad, Molecule and Sequence. Molecule is the model of product known to all: it is a complete single product which within the value creating model forms a 4 points picture in. Monad is a depleted product. It has only the basic functional components, no brand, service and relationship components. Functional components of Monad cannot be differentiated. It is simply one, unified product which is offered in the same version at the same price. The author of the

concept gives as an example the service of technical inspection of trains, the positive result of which is visible in the form of a stamp in the registration document. On the value map Molecule is placed in the right hand upper quadrant close to zero point. The remaining 3 points (B, C, D), co-creating the image of the product will not occur. The Sequence is a particular set of products, a series of events that generate demand for the material assets or services, cause the creation of series of products remaining in a logical relation with each other, the center of which is the group of single buyer's needs. Individual products may be offered by different players—relating to each other or not. Any involved subject may play the role of offer integrator, but it does not always happen and is not required.

The Sequence can be analyzed as a Sequence of Molecules, each of which creates the value in an individual way. The starting point for the Sequence can be any component creating value of the first Molecule, although it is unlikely that it could be a relationship component, because the relation is not established yet. The elements connecting the individual Molecules can be functional components, e.g. buying a car and buying insurance. In a specific case this dependence can be transformed into a relation, if the car seller offers an insurance discount for a particular insurer. A Sequence based on image components can also occur e.g. if the service offers branded oil to the owner of a good brand vehicle. A very good way to build the Sequence is to use the service component. Information is a common additional service, usually provided free of charge. A customer, for example, a hostel guest, who got the necessary information about food services, will be more satisfied with the service, and the recommended restaurant will become another link in the Sequence of services the customer use. In any case, the Sequence can be presented on the value creating model as a series of transitions between quadrants of the map.

8 Build-A-Bear as an Example of the Advanced Product

A good example of the variety of methods to increase the product value and usefulness of the presented model can be the Build-A-Bear [10] concept. It is hard to imagine a more popular, non-branded and also hardly recognizable product than a teddy bear toy. Thou we know the Paddington Bear well, but it is rather a collectors' item, than a toy for children. Besides, the brand under which it is sold comes from literature and has some historical meaning. Definitely, more popular on the toy market are brands such as Lego blocks, Barbie doll or Kinder Surprise egg. Against their background Build-A-Bear looks really impressive.

The starting point (B): a popular toy, which hardly absorbs the technical innovations, with a design accessible to everyone, is very likely to spark price competition. Achieving the high profit margin and effective market differentiation is almost impossible.

The owner of the microenterprise started selling teddy bear in a single workshop store in 1997. Quickly she noticed that the children were very happy if the bear was

made according to their suggestions. Thus two new value creating components occurred: relationship component (D1—asking customers about their expectations) and the functional component (B1—fulfilling those expectations). Both components had a small impact on the unit costs. The result was an increase of the image components value. Such increase among children eager to exchange information about their favorite toys was spontaneous without involving large investments (A1). The company has grown successfully and employs properly trained people to gather information about children's opinion (D2) and prepares suggestions as to the size and appearance of the teddy bears (B2) and involves children in the process of creating the personalized toy (C2). The company has developed a distribution system using the franchise method, has prepared additional services, such as parking, dining and playrooms for children's parties (C3), has equipped the bears with a variety of inbuilt technological gadgets (the functions of speaking, singing, etc.) (B2), created the custom bear naming as well as issuing certificates of "birth" and the rules etiquette of birthday celebrations (D3).

At the same time a number of gadgets, such as clothes and furniture for the teddy bear appeared (B4). These circumstances increase the image components value—again without the need for special expenses, because, for example, fashion for preschool and school parties spreads rapidly (A4) (Fig. 6).

The next stage of product development is the Internet: a shop, a communication tool, games environment (Bearville) and community—new services (E1), a new tool to build relations (D4) and strengthen the brand (A5).

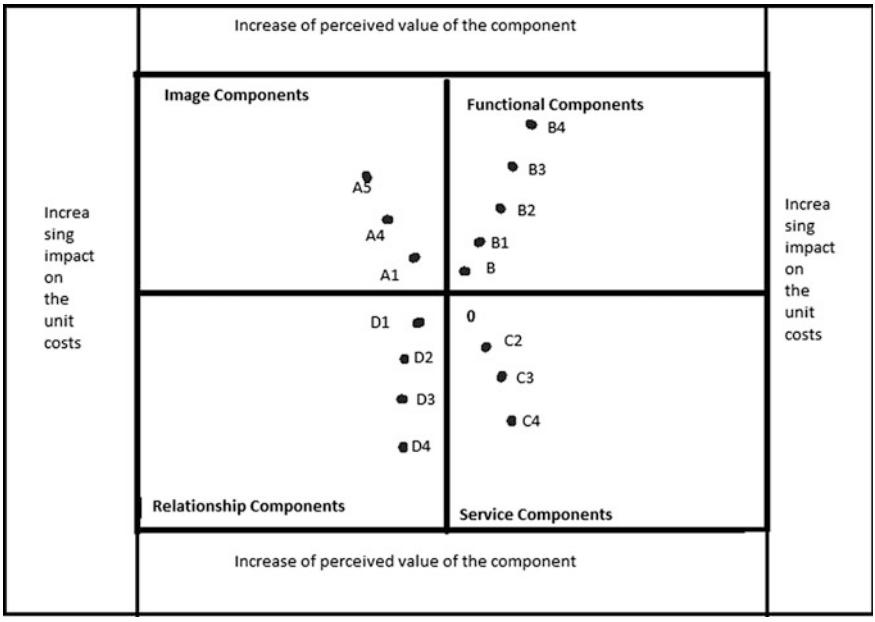

Fig. 6 Development of the Build-A-Bear product value

Currently the company shows approx. $ 0.5 billion of annual turnover, employs 5,500 workers, and has 400 stores in more than 20 countries around the world.

9 Conclusions

The essence of each market transaction is subjective consent of the buyer to equal the perceived value and price of the product. Managers must be pretty sure that such decision are likely to take place before the product is implemented. The presented value model should facilitate the analysis of the components and assess their impact on the value and calculate the cost consequences of using them. In future the model should quantitative, which means the ability to present basic relations in figures. In practice such solution ore difficult to obtain and the fully operative model of the value may never be gained, but the marketing and financial success will be achieved by the player who eliminates the phenomenon of consumer surplus and develops the range of products, in which every buyer can find the perfect combination of price and value.

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The Paradigm of Effectiveness of Public Hospitals

Agnieszka Parkitna and Magdalena Gądek

Abstract This paper reviews various analysis and evaluation methods for measuring hospital effectiveness. Differentiation of hospitals due to the legal subjectivity. The specificity of the activities of hospitals as the main determinant of effectiveness measurement. Identification of the determinants of the measurement of efficiency in public hospitals. Identified in a set group hospitals, which can be considered as the most effective and which might be a model group. Established a list of possible non-economic factors that determine the efficiency of hospitals. At the end of the model they created prerequisites efficiency of hospitals, which can be a basis for further scientific consideration of this topic—The paradigm of the measurement of efficiency in public hospitals-evaluation of model.

Keywords Measuring effectiveness · Effectiveness of public hospitals · Paradigm of effectiveness

1 Introduction

One of the current and still unresolved problems in the Polish health care is growing indebtedness of independent public health care facilities (ZOZ). According to the Gdansk Institute for Market Economics, the present total indebtedness of Polish health care facilities has exceeded the level of PLN 10 billion. At the end of 2015, total liabilities of hospitals exceeded PLN 10 billion. The most visible effect of excessive indebtedness is a high level of payable liabilities of PLN 2.1 billion [1].

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However, on this background, some facilities turned out effective. In 2001, Williams, with his report, started a broad international debate about effectiveness of health care facilities and the health care system alone, and some important conclusions are clear [2]:

- Ultimate responsibility for the performance of a country's health system lies with government
- Dollar for dollar spent on health, many countries are falling short of their performance potential
- Health systems are not just concerned with improving people's health, but with protecting them against the financial costs of illness
- Within governments, many health ministries focus on the public sector, often disregarding the—frequently much larger—private finance and provision of care

It is already known that health care system in Poland is characterized by a considerable disproportion of available resources in respect of expenses incurred by health care facilities. It results in more and more difficult conditions for public health care facilities to survive on the market of medical services. In order to keep balance in financing and obtain proper efficiency, three elements must be balanced:

- financing (raising funds by health care facilities),
- generating (costs of a facility incurred in the process of provision of medical services),
- functioning (supply and impact on demand by health care facilities).

The notion of effectiveness of hospitals is ambiguous, and the scope of the issues is comprehensive, which results in quite a high degree of its complexity. Holligsworth dokonał pierwszy próby uporzadkowania tej tamatyki. The inability to measure the real output of the health care industry, changes in health status and the low quality of available data still leads to problems. The techniques are still criticised, but are continuingly being refined. However, estimated results may still be sensitive to changes in the basic assumptions or specifications of the models used and the characteristics of the environment in which the units operate. Thus, the results may be valid only for the units under investigation, and not necessarily be generalizable. Different modelling approaches have advantages and disadvantages and the choice of the most appropriate estimation method should depend on the type of organisations under investigation, the perspective taken and the quality of the available data. Nevertheless it is an important finding that public hospitals in general continue to demonstrate less variability than private hospitals [3]. The diversity of the effectiveness of public and private sector indicate among other things, the study Górski and Stadtherr [4].

It means that hospitals can be divided into specified groups, by the approved criteria. It implies an observation that financial performance in these groups of hospitals may substantially vary between each other. It should be thus examined whether among this set there is a group of hospitals that can be considered as the most effective and that may be a model group, as well as which factors determine effectiveness of these entities.

2 The Essence of Effectiveness of Hospitals

The contemporary meaning of the notion of hospital's effectiveness is comprised of [5]:

- efficiency in technical and economic perspective of Harrington Emerson;
- competency in organizational and bureaucratic perspective of Max Weber;
- ability in praxeological perspective of Tadeusz Kotarbiński;
- functionality in humanist perspective of Richard Beckhard;
- communication skills in personality perspective of David J. Lawless;
- morality in behavioral perspective of Kazimierz Obuchowski.

Many economists, when considering the notion of effectiveness, refer it to operating effectiveness, which means that actions will be efficient only when they are characterized by efficiency, gainfulness and economy [6]. It should be noted that gainfulness has absolute advantage of the system, while economy has relative advantage. In broad understanding, effectiveness corresponds to all efficiency categories, and in narrow understanding only to economy [7].

Efficiency is identified with effectiveness quite frequently. The difference between these two terms consists in the fact that effectiveness refers to doing things in an appropriate manner, while efficiency refers to doing the right things [8]. Efficiency is a positively assessed compliance between the result of the action with its planned goal, on the other hand, however, effectiveness is a feature of many actions that give positive result regardless of whether or not it was intentional [7]. The true art is to increase effectiveness without further investments. ISO 9000 standards also differentiate both terms defining efficiency as degree to which the planned actions are completed, and the planned results are achieved and effectiveness as a relationship between the results achieved and the used resources [9]. Due to a discrepancy between the understanding of effectiveness and efficiency of management results, having the same resources and in the same economic conditions organizations may achieve completely different economic results. In the theory of efficient operation, effectiveness corresponds to economy. namely the most desired condition in the real world is a the combination of efficiency and economy with gainfulness [10].

In the theory, two approaches to assessing effectiveness are presented, i.e. goal-oriented approach where the object of assessment is the degree of achievement of complex goals, and system-based approach that assesses the degree of use of resources [11]. The first of these assessments is identified with the English term effectiveness, which means effectiveness, efficiency, purposefulness, where the measure of such effectiveness is the degree to which goals get closer to the results of conducted operations. On the other hand, the second one is identified with the English term efficiency, which means ability, efficiency, economy, measured as a relation of the achieved results to sustained outlays. Using the goal-oriented approach and the system-based approach to the assessment of a hospital's effectiveness, it should be noted that effectiveness of this special organization increases

together with increase in the achievement of its goals, and reduction in outlays incurred for their achievement. To sum up, a hospital's effectiveness may be identified with lack of wastage [12] of resources; conducting to achieving goals with reasonable use of the sources of financing.

Cost effectiveness in hospitals has become a way to optimize business operations. To achieve cost effectiveness, health services should be performed in a way enabling achieving a positive result at the lowest cost. It is particularly important when the organization has limited resources, including funds [13]. Cost-effectiveness analysis compares the costs and health effects of an intervention to assess the extent to which it can be regarded as providing value for money. This informs decision-makers who have to determine where to allocate limited healthcare resources. It is necessary to distinguish between independent interventions and mutually exclusive interventions. For independent interventions, average cost-effectiveness ratios suffice, but for mutually exclusive interventions, it is essential to use incremental cost-effectiveness ratios if the objective—to maximise healthcare effects given the resources available—is to be achieved.

3 The Specific Character of Operations as a Determinant of Effectiveness

According to the Act on medical activity, a hospital is a business of medical entity in which the entity conducts medicinal activity like hospital benefits [14]. The essence and the object of medical activity are health benefits [15]. Provision of stationary, 24-h hospital benefits is the main goal of operation of a hospital, regardless of its legal form or type of the founding body [16]. It should be emphasized that each hospital performs three main bundle of goals: medical, social and economic goals [17]. Researchers classify hospitals in Poland by grouping them by specified criteria. The binding classification of hospitals is presented in Table 1.

The execution of tasks of the health care system in Poland is entrusted mainly to health care facilities. Each health care unit has a statute that, in most cases, is drawn up by the founding entity. Act on health care facilities sets out a closed list of these entities (Article 8). Depending on the founding entity of a health care facility, they are divided into public and non-public health care facilities. Public hospitals belong to the group of hospitals classified by the nature of the founding entity. This group includes independent public health care facilities and budget facilities (state, local government) and local government budget facilities.

Independent public health care facilities perform health benefits under an agreement signed with the National Health Fund, limiting the number and type of provided benefits to the volume included in the agreement. Moreover, these facilities may perform paid medical services for the benefit of other recipients, which include non-insured persons, other health care facilities, as well as employment establishments. The founding body of an independent public health care facility may be: minister, central state administration body, province governor, local government

Table 1 Classification of hospitals (*Source* [18], pp. 58–64.)

No.	Division criteria	Type of hospitals
1	Nature of the founding entity	Public
		Non-public
2	Founding entity (body)	Local governmental
		Departmental (Ministry of Health, Ministry of National Defense, Ministry of Justice, Ministry of Internal Affairs and Administration)
		Church or denominational union
		Commercial law companies
		Civil law companies
		Non-governmental organizations
3	Territorial range of operation	Municipal, district, regional
		Provincial
		Regional
		Nationwide
		Specialist for a given professional group
4	Number and type of medical specializations	General
		Specialist
5	Availability of benefits (granting benefits for)	Total population
		Population of a specific area
		Specific group (field hospital, hospital of a penitentiary facility)
6	Scope and types of the offered benefits	Basic
		Monospecialist
		Multispecialist
7	Period of treatment	Short-term care
		Full-time
		Night
		Home hospitalization
		Long-term care
		Hospice and palliative care wards
8	Size of hospital	Low
		Average
		High
9	Ownership of hospital	Public
		Local governmental
		Cooperative
		Private

unit, public medical university, public university running education in the field of medical services, Medical Center of Postgraduate Education. The activity of independent public health care facilities is financed with regard to the scope, which

means that all costs beyond health benefits are covered by the founding body (e.g. personnel or materials). Independent public health care facilities are characterized by a double-sided form of financial economy, which means self-financing of costs of activities and liabilities from held funds and revenues earned by the hospital. Hospitals being independent public health care facilities have a substantial impact on the size of funds that depends on the number of completed contracted health benefits under common health insurance and paid medical services for other recipients. It should be also emphasized that the scope of self-reliance of an independent public health care facility in relation to other forms of public hospitals is considerable. It manifests itself in having legal personality, which implies the possibility of managing on their own asset components received from local government units and assets bought or donated, as well as the possibility of diversifying sources of financing. An independent public health care facility has a broad scope of decision-making rights, among which the following can be distinguished: the right to dispose of full financial excess, the right to determine prices for health benefits, the right to incur credits, the right to fix own employee rewarding principles.

Public hospitals being budget-financed units or budgetary establishments concentrate their activities on health benefits pursuant to needs reported by citizens. They are subordinated directly to a state administration body or a local government unit body. Their activities are funded with regard to the scope, which applies not only to provided health benefits, but also to financing of materials and personnel. This type of public hospitals is characterized by one-sided form of financial economy, which means that they only mediate in spending funds received from the budget. Moreover, budgetary facilities and establishments have a limited scope of self-reliance. They manage entrusted part of municipal property and allocated funds. They do not have impact on the volume of budget funds. They are characterized by lack of legal personality, and limited decision-making rights [18].

4 Method of Financing Health Care Facilities as a Basic Limitation of Economy and Hospitals

Since the beginning of their existence, health care facilities have stood out with unprecedented way of financing. As opposed to other sectors of the economy, the health sector does not involve a typical commercial trade—cash for goods or services, namely direct participation of two entities: the buyer and the seller, provided that the latter seeks to earn profit on the transaction. In the health protection system a transaction involves three entities:

- the payer—responsible for collection and redistribution of funds,
- the manufacturer—responsible for the provision of medical services,
- the patient—equivalent of a customer in the traditional commercial exchange, and payment for the services is made before previous payments in the form of health care premiums.

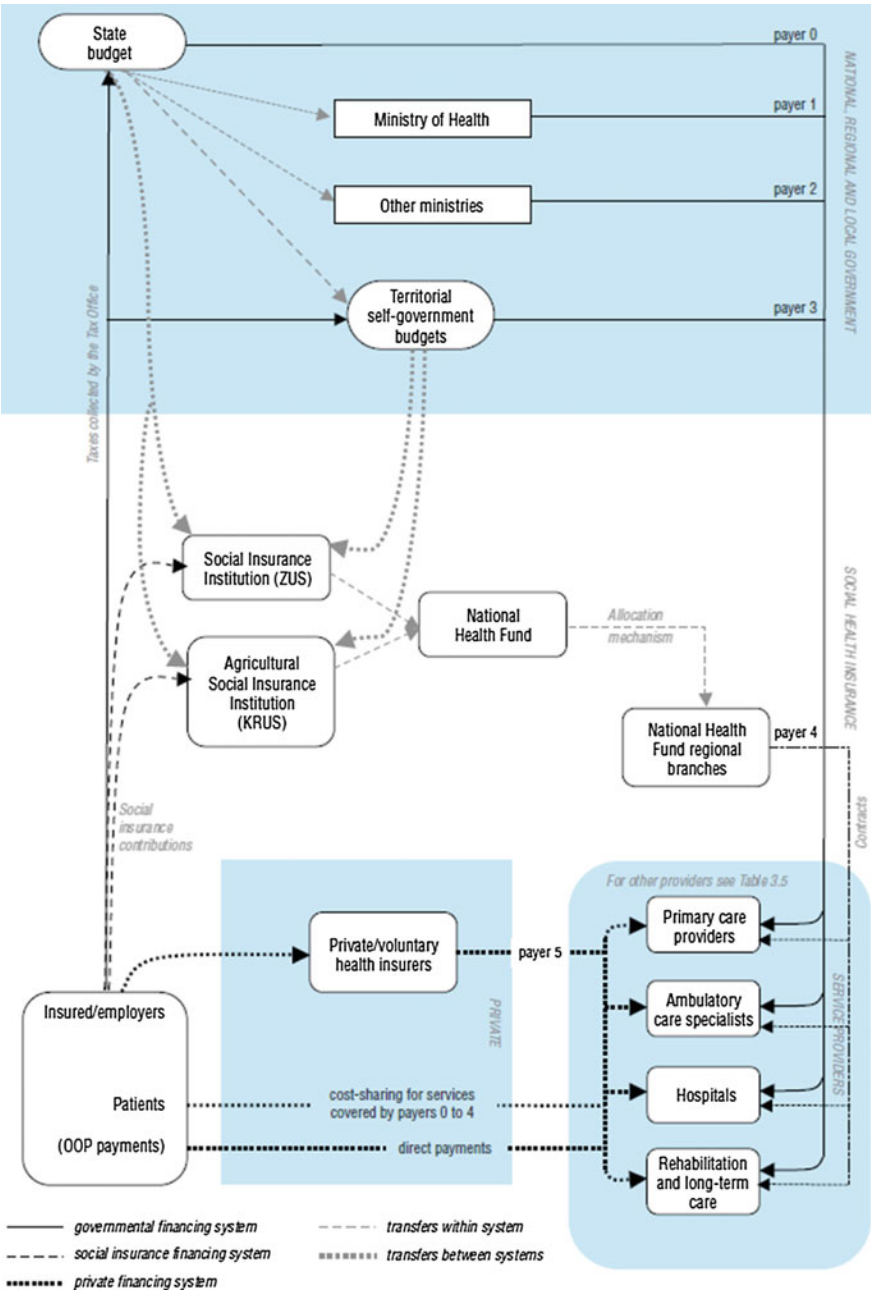

Fig. 1 Financial flows (*Source* [24])

An additional difference is also the fact that the provider (the manufacturer) does not aim at earning profits on its activities, and, furthermore, is exposed to losses by pursuing top-down entrusted tasks. Of course, this solution is not encountered in the whole health sector; however, currently, it is most often used, for instance owing to the lack of developed private sector of medical services in Poland. Total image of financing of the health care system (Fig. 1) includes three main dimensions of the classic analysis from the area of public finance [19]:

- analysis of sources and mechanisms of raising funds for health protection,
- analysis of costs of manufacturing health protection benefits, including types, changes in structure and dynamics,
- analysis of expenses incurred by all entities to satisfy their health care needs.

The fact that independent public local government health care facilities are institutions that cannot generate profit, does not exempts them from the obligation to monitor their financial situation. Therefore, it does not mean that financial result or e.g. lack of liquidity is insignificant for them. Health care facilities, just like organizations operating to earn profit should (let alone the obligation of this phenomenon) examine their financial condition.

The main tool commonly used by various organizations is financial analysis. Until 1999, analyzing financial condition of most health care facilities did not make any sense, since most of the then facilities were operating as a budgetary unit, firmly dependent on the state. However, when health care facilities were transferred to local governments and independent health care facilities were established, financial analysis in the health care system became common.

Legal conditions under which the discussed public hospitals operate affect effectiveness of their operation, reflected in the net profit or loss understood as total result on business operations [20] and the synthetic measure of assets management [21].

5 Effectiveness Determinants of Public Hospitals Test Results

For many entities the only source of information about hospitals' situation are financial statements. The image they present does not cover many aspects significant in the assessment of hospitals' achievements. It is obvious that measure of economy is financial result that includes, as a result of difference between revenue and economic benefits. Effectiveness measured in this way ignores the aspect of cost of capital. Financial result takes account only of a perspective of the hospital's owner and is expressed only in cash. For evaluation of effectiveness of hospitals in many aspects these are data insufficient and imperfect for the total evaluation. They required to be supplemented by non-financial management data skipped in the

process of traditional accounting. Objectives designated to hospitals (medical, economic, social) are multiple thus measures of their achievements should be multifaceted [18].

In 2015, a list of 400 largest hospitals in Poland for 2014 was published [22]. The statement contained 313 public hospitals and 87 non-public hospitals. Among public entities, there were 181 budgetary units and establishments and 132 independent public health care facilities. Summary net financial result of all budgetary units and establishments contained in the statement amounted to PLN −221 430 929.90, and independent public health care facilities amounted to PLN 106 065 396.79. It should be noted that independent public health care facilities have more than two times smaller indebtedness in the studied group than budgetary facilities and establishments. In order to find an answer to a question contained in the introduction: whether there is a group of hospitals that can be considered as the most effective and may potentially be a model group (Table 2).

From the point of view of economy as the most measurable effectiveness coefficient, from the statement it can be seen that average financial result for both groups of hospitals is negative, and independent public health care facilities have more than twice smaller indebtedness than budgetary units. The U Mann-Whitney test demonstrated that there is no statistically significant difference between average values of financial results between the distinguished groups of hospitals ($U = 11219.500$; $p = 0.358 > 0.05$). Due to the fact that independent public health care facilities have a greater impact on shaping their financial result, and the average of its value is higher, this group of hospitals, as slightly more effective, was chosen for further tests. On the selected group of hospitals survey tests were conducted, and the collected data were subjected to statistical analysis, including exploration factor analysis to determine organizational factors affecting the level of their effectiveness.

Tests started from conducting a survey on an indicated group of hospitals. A survey was directed to health managers managing 132 largest independent public health care facilities in Poland. The research survey comprised 10 principal questions concerning the selected factors identified based on the decomposition of the McKinsey 7-S model. The answers were indicated on a 7-grade Likert scale.

After conducting surveys, 37 completely completed return surveys were collected, which is effectiveness of 30 %. The analysis of survey reliability using Cronbach's alpha (α) showed that the survey can be considered as reliable [23] $\alpha = 0.926$. In the first place, an initial statistical analysis of the central tendency measures and variable distribution shape measures was conducted (Table 3).

Table 2 Net financial result in public hospitals

Budgetary units/establishments		Independent public health care facilities	
Average	PLN −1 223 375.30	Average	PLN −803 525.73
Standard deviation	PLN 6 713 880.03	Standard deviation	PLN 5 673 548.40
Max. value	PLN 15 853 219.00	Max. value	PLN 14 665 987.16
Min. value	PLN −55 111 600.00	Min. value	PLN −34 560 539.00

Table 3 An initial statistical analysis of variables

Coefficient of variable	Average	Median	Dominant	Standard deviation	Variance	Skewness	Kurtosis
Management system	4.41	5	5	1.62	2.64	−0.13	−0.83
Management style	4.65	5	5	1.58	2.51	−0.09	−0.97
Attributes of medical employees	4.89	5	5	1.47	2.15	−0.42	−0.60
Attributes of administrative employees	4.57	5	5	1.39	1.92	0.12	−0.67
Attributes of economic employees	4.35	4	4	1.62	2.62	−0.03	−0.81
General strategy	4.84	5	5	1.30	1.70	−0.29	−0.85
Directional strategy	4.73	5	5	1.17	1.36	0.11	−0.66
Structure	4.64	5	5	1.59	2.53	−0.06	−0.99
Internal culture	4.30	4	4	1.56	2.44	−0.09	−0.82
External culture	4.23	4	5	1.49	2.23	−0.10	−0.60

The average value of 10 coefficients of latent variable ranges from 4.23 to 4.89. The analysis of dispersion measures indicates that the most strongly concentrated results around the average were recorded for directional strategy (1.17). The largest dispersion was shown for management system and attributes of economic employees (1.62). The distribution shape measures analysis indicates that no coefficient corresponds ideally to normal distribution. Skewness coefficients divide the distribution of the received results into skewed to the right and to the left. The distribution of answers indicates that the respondents more often were inclined to mark low values on a 7-grade Likert scale. The results obtained for other coefficients are characterized by coarse skewed distribution (skewed to the left). From the analysis of kurtosis it seems that all distributions are platykurtic, and the results are scattered around the average. Results of tests checking distribution normality are presented in the table (Table 4):

Analysis of received results indicates that coefficients without normal distribution are: management style, attributes of medical employees, attributes of administrative employees, and organizational structure. For other coefficients there are no bases to reject the hypothesis about distribution normality.

In order to check which factors have significant impact on effectiveness, the analysis of correlation was conducted respectively for factors with normal distribution: test of significance of r-Pearson correlation coefficient and test of rho-Spearman for other coefficients (Table 5).

A statistically significant relation between a given coefficient and effectiveness is present for the variables for which its value is greater than critical value. The tests demonstrated that this group includes: management system, attributes of economic employees, internal and external culture (Table 6).

Table 4 Results of tests checking distribution normality

Coefficient of variable	Shapiro-Wilk	
	Statistics	Significance
Management system	0.95	0.07
Management style	0.92	0.02
Attributes of medical employees	0.92	0.01
Attributes of administrative employees	0.94	0.04
Attributes of economic employees	0.95	0.09
General strategy	0.94	0.05
Directional strategy	0.97	0.53
Organizational structure	0.93	0.03
Internal culture	0.95	0.13
External culture	0.96	0.18

Table 5 Result of the analysis of Pearson's correlation

	Pearson correlation	Significance (two-sided)	Critical value of Pearson correlation coefficient
Management system and financial result	0.5620	0.00	0.2746
Attributes of economic employees and financial result	0.5580	0.00	0.2746
General strategy and financial result	0.0865	0.61	0.3246
Directional strategy and financial result	0.1548	0.36	0.3246
Internal culture and financial result	0.5740	0.00	0.2746
External culture and financial result	0.5950	0.00	0.2746

Table 6 Result of the analysis of rho-Spearman's correlation

	Correlation coefficient	Significance (two-sided)	Critical value
Management style and net financial result	0.7710	0.00	0.4674
Attributes of medical employees and net financial result	0.2249	0.18	0.3936
Attributes of administrative employees and net financial result	0.3490	0.03	0.3936
Organizational structure and net financial result	0.7800	0.00	0.4674

Table 7 Kaiser-Mayer-Olkin and Bartlett's tests

Kaiser-Mayer-Olkin and Bartlett's tests		
KMO measure of sample adequacy		0.75
Bartlett's test of sphericity	Approximate chi-squared	665.05
	Df	15.00
	Significance	0.00

Table 8 The Kaier's Criterion

Total explained variance			
Component	Sums of squares of loads after separation		
	Total	% of variance	% accumulated
1	5.53	92.16	92.16

A statistically significant relation between a given coefficient and effectiveness there is present for the variables for which its value is greater than critical value. The tests demonstrated that this group includes: management style and organizational structure.

The analysis of correlation between coefficients and effectiveness measured through the prism of net financial result demonstrated that, while creating a model for effectiveness determinants, the following coefficients should be considered: management system, attributes of economic employees, Internal and external culture, management style and organizational structure.

Before beginning exploration factor analysis, it was verified whether the examined determinants have suitable statistical properties: standard deviations are different from zero, coefficients of variables are measured in quantitative scale, the measurement was made in the same units, as well as there are no data shortages. Then the coefficient of Sample Adequacy K-M-O was determined and Bartlett's test of sphericity was conducted (Table 7).

The measure K-M-O is at an acceptable level higher than 0.5, and the results of Bartlett's test of sphericity indicate that the hypothesis about statistical insignificance of correlation coefficients should be rejected and the alternative hypothesis ($p < 0.05$) should be adopted.

Kaier's Criterion and Cattel's Criterion clearly indicate that there is only one group of factors affecting financial result of hospitals (Table 8).

6 Conclusions

To sum up, the purpose of the test was to identify a group of hospitals that can be considered as the most effective and to create of a list of factors that determine their effectiveness measured by the financial result. In the conducted analysis of test results, it was demonstrated that: independent public health care facilities may be considered as the model group and there is a group of six factors determining their level of financial result (Table 9):

Table 9 Determinant of effectiveness

Matrix of components	
Determinant of effectiveness	Component
	1
Management system	0.986
Attributes of economic employees	0.981
Internal culture	0.979
External culture	0.954
Management style	0.929
Structure	0.928

Management system is understood as a set of formal and informal procedures that makes it possible for the hospital to operate on the current basis. Attributes of economic employees is the sum of professional qualifications, skills, knowledge, experience and motivation. Internal culture of a hospital consists of basic assumptions, standards and values. External culture of a hospital consists of language, physical, behavioral and personal artifacts. Management style is an organized management process of subordinates using specific measures, forms, methods to achieve the adopted goals of a hospital. Organizational structure is perceived by its characteristics-formalization, specialization, hierarchy and centralization.

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