Information Systems Architecture and Technology

The Use of IT Models for Organization Management

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Wrocław University of Technology

Information Systems Architecture and Technology

The Use of IT Models for Organization Management

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PART 3. MANAGEMENT OF FINANCIAL INFORMATION IN BUSINESS ORGANIZATIONS

INTRODUCTION

In effect, the computer can become your notebook, but it can't be your mind.

Justin Mamis, *The Nature of Risk*,
Stock Market Survival & the Meaning of Life,
Addison-Wesley Publishing Company1993

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 consists of a scope of strategies and practices used in corporations to explore, represent and distribute knowledge. 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

Information technologies take place a great role in this area. The computer is a useful machine in making managers' work easier. As J. Mamis says "Once experience has been gained in understanding the market language of these indicators, the computer can do all of the math much more accurately and efficiency than human beings." But from the other hand, there is not possible to build computers capable "of equaling or exceeding the thought process of the human mind". The computers are able to collect and select the information can make some statistics, but decisions have to make managers basing on their experience and taking into consideration computer support.

So, in summary the following associations can reasonably be made:

- Information relates to description, definition, or perspective (what, who, when, where).
- Knowledge comprises strategy, practice, method, or approach (how).
- Wisdom embodies principle, insight, moral, or archetype (why).

An improvement of decision making process is possible to be assured by analytical process supporting. Applying some analytical techniques, as: computer simulation, expert systems, genetic algorithms can improve quality of managerial information. Managers have to remember that "What's worked before, especially in the recent past, becomes an acceptable pattern of behaviour – except that the market will then do

something similar, but different enough to deceive us" Combining analytical techniques and building of computer hybrids gives synergic effects – additional functionality- which makes managerial decision process better. Different technologies can help in accomplishing managerial decision process, but no one like information technologies, which offers differentiable advantages.

The book titled *Information Systems Architecture and Technology. The Use of Information Technologies for Organization Management* in gain to address very hot topics in the field of today's various computer systems based applications – is devoted to information systems concepts and applications supporting exchange of goods and services by using different business models and exploiting opportunities offered by IT systems.

The selected and reviewed chapters have been divided into three parts:

Part 1. *Models of Information Management for Business Organizations*
Part 2. *Knowledge Management for Non-Profit Organizations*
Part 3. *Management of Financial Information in Business Organizations*

The book provides an interesting representation of research in the area of contem-porary management information systems – concepts, models, services and applica-tions, requirements and models.

The first part – *Models of Information Management for Business Organizations* – presents considerations of knowledge based organizations. Here is considered process of collecting, representing, protecting and distributing the business information. Here are showed examples of practical use that information in managing process.

In the second part – *Knowledge Management for Non-Profit Organizations* – some selected models of non-profit organizations' management are considered. Efficient managing of the non-profit organization requires special information and proper cost system.

The third part – *Management of Financial Information in Business Organizations* – considers special models designing for finance and investment management. Starts with a statistical methods of financial analysis and then discusses some special models for financial and investment decisions taking – focuses on various methods that are risk undertaking in managerial decision process.

PART 1 MODELS OF INFORMATION MANAGEMENT
FOR BUSINESS ORGANIZATIONS

Dynamic development of the IT technologies creates the possibility of using them in the dynamic management process modeling and decision making processes sup-porting.

The Chapter 1 concentrates on the development of a multi-domain knowledge repre-sentation structure. A novel structure is introduced by combining the SOEKS (Set of Experience Knowledge Structure) with a feature selection model. This new structure can be used to extract useful knowledge from various sources such as web crawler, CVS

files and among others. In addition, it compares with the extracted experiences in order to guides decision maker to make precise decisions. The model supports knowledge representation for collecting, storing, improving, and reusing decisional experience from formal decision events.

The use of the information for the decision of any problems is connected to necessity of its distribution. The Chapter 2 presents a problem of the coordination of the coding method with characteristics of a liaison channel and also to provide protection of the transmitted information against possible distortions. Transfer of the information is carried out due to use of a communication facility. The liaison channel is a material environment, and also physical or other process by means of which transfer of the message is carried out, i.e. distribution of signals to space eventually.

In the Chapter 3 problem of estimation of dynamic object orientation is presented. This problem is important in the point of view of human movement monitoring and analysis. In order to solve it the Authors consider processing data from accelerometers and gyroscope using. Complementary filter are used to combine signal from accelerometers and gyroscopes. In this work ubiquitous computing systems called SmartFit, designed to support endurance and technical training of either recreational and elite athletes, is presented.

In the Chapter 4 a classical model of failures is considered in that successive failure-free times are supposed to have exponential distributions and are followed by exponentially distributed times of repairs. Basing on information about the number of failures in a number of periods of the same duration in the past, the method of estimation unknown parameters of the model based on renewal function is proposed. Next, predictions of the most important reliability characteristics are found using classical regression technique.

And in Chapter 5 the model of production system is presented, the production system is described by the processes routes of jobs, operation times of jobs, deadlines of jobs and butch sizes of jobs. Here was used the renewal function to estimate the reliability characteristics of the production system to reach the robust basic schedule. Basing on information about the number of failures in a number of periods of the same duration in the past, the method of estimation of unknown parameters of the model based on renewal function is proposed. In the chapters the Authors propose the method for exploitation of the system's constraint – how to maximize utilization of the "bottle neck", how to plan its technical inspections.

The Chapter 6 considers purchasing decisions on the example of computers purchasing. Highly competitive business of notebook computers and their diversity make the process difficult. Therefore, using the decision support methods in evaluating and selecting alternatives is the beneficial way to help the IT managers choose the best products. The objective of this work is to analyze possibility of applying a method that calculates additional measures for groups of criteria. The Authors propose Generalized Parameter Method to support notebook purchasing decisions and present a case study to demonstrate that it can be very useful during the notebook selection process in organizations.

In the Chapter 7 a novel concept of implementation of an encryption and decryption unit is presented. It is based on using reversible logic. The idea of reversible logic was create for quantum computers. Was developed a reversible gates and methods of reversible function synthesis. In this work a design of a cipher unit built with reversible gates is described. The reversible gates was simulated using FPGA device. Implementation of this project was presented in VHDL and embedded in FPGA device. Synthesis and simulation of project was done using Altera Quartus system and Aldec Acive-HDL system.

PART 2. KNOWLEDGE MANAGEMENT
FOR NON-PROFIT ORGANIZATIONS

Non-profit organization are special businesses. Does not require from them to generate profit but they should be efficient. Special requirements to the organization process system follow huge and permanently growing knowledge and need to be modeling.

The Chapter 8 presents a study aimed at identifying the factors influencing university choice by applicants. Many factors influence the potential students' decisions. Because of the increasing role of competition on the educational services market there is required to study the needs of future students and adjust their offer and study conditions to the latter's expectations.

In the Chapter 9 Activity Based Costing has been implemented for cost of education evaluation In the chapter the novel method is presenting which is a combination of the ABC and Data Envelopment Analysis method, and tailored for the needs of higher education costing.

The authors of the Chapter 10 propose application of the management accounting tools, which is cost account of the activities, as the method constituting information basis for the managers. The method being presented should serve valuation of the products of research works, supporting thereby the process of rational application of the financial resources through increase of effectiveness of the performed tasks.

In the Chapter 11 a case study of one faculty of a Polish university is presented. The results of its costing system is showed and as it turns out to be not useful from the managerial point of view. A suggestion of its modification is formulated. The whole context of the problem of university costing system is also presented, showing that the proposed direction of changes is necessary.

The Chapter 12 presents the concept of an environment for the production (testing) of service-based applications. The authors have adopted a solution within the frame of which the completed manufacturing process of applications designed for the recruitment of students, along with the IBM's Quality Manager platform and the IT infrastructure constructed for the needs of this application can provide a common research environment for service application testing. Then the application for the recruitment of students and the possibility of its construction based on SOA architecture has been discussed and the solution has been evaluated.

PART 3. MANAGEMENT OF FINANCIAL INFORMATION
IN BUSINESS ORGANIZATIONS

As was known, all investors and managers like the idea of achieving high returns on the business activity, most tend to dislike the high risk that are associated with anticipated high returns. So, before the decision is made, the results of managerial decisions need to be evaluated especially from the financial point of view. Many methods are considered in the evaluation process. Many of them use the computer technologies. The success of the firm depends on many factors. The most important factor is its ability to absorb knowledge and to create knowledge in innovation processes

The Chapter 13 shows results of investigation of 34 corporate bankruptcy prediction models such as Beaver model, Altman's model and in particular Polish models including models of: Mączyńska, Prusak, Hadasik etc. Aim of this study is to conduct a comparative analysis of selected models in terms of predicting bankruptcy of enterprises. This research also aimed at selecting the most versatile models and identifying common features in their construction, which embody predicting capabilities.

In the Chapter 14 the Author describes a new approach to integrate concepts of simulation modeling and accounting for the generation of financial statements in production processes. It provides the ability to generate and analyze financial ratios. The new integrative approach is the object representing the discrete events (e.g. sale or purchase) object multiplication to physical aspect object and book-entry form object. Examples of models that use the approach are presented and discussed.

In the Chapter 15 the existent achievements in Value Based Management (VBM), including especially those concerning Economic Value Added (EVA), is discussed. In the area of performance reporting, a new measure EVA Momentum was elaborated on; difficulties concerning value measurement at the operating levels of management were emphasized. The Author decided to restrict the Value Based Management to its most popular value creation measure: Economic Value Added (EVA). The goal of this chapter is to answer the question whether Economic Value Added is a fully explored subject or there is still something worth investigating. If there is still something to study then which areas of VBM does it concern.

The Chapter 16 is about estimating the investments profitability, especially taking the discount rate into consideration. Despite the fact that many authors agree about it, in practice it is assumed that the discount rate should be static when it is used to lead cash flows to the paralleled period. It will not reflect the real change of money value in time. Taking into account the influence of many factors that changes in time, using dynamic discount rate, it is proposed to be used in estimating the investments profitability.

The Chapter 17 considers problems of the companies' mergers. The costs of such operations can be large, but often managers are willing to pay any price, in order to pursue important long-term business strategies. In the chapter some mergers' strategy are discussed on the example of Polish economy.

In the Chapter 18 Authors proposed a new method of the calculation of the one of the stock exchange indices. The research was conducted on the Stock Exchange in Warsaw.

The model is based on a relation between analyzed banks and an analysis of their stock price changing. The results of the model were compared to the results of the index WIG-BANKI and two banks (PEKAO and PKOBP) with the largest percentage contribution in that index.

In the Chapter 19 the Authors shows the martingale method to price some catastrophe bond. Then they conduct Monte Carlo simulations to analyze influence of various parameters on the calculated bond price. The increasing number and value of losses of natural catastrophes leads to problems with financial reserves for many insurers. So the new financial mechanisms like catastrophe bonds (in abbreviation cat bond) or options may be used to cope with consequences of natural disasters.

The book contains contribution accepted by revisers the submitted works. We hope that the book will be considered as a forum for presentation of original works on a good professional level and for discussions integrating different subject of enterprise management and changes as well as information systems planning, designing, development and implementation.

We thank all Authors who have submitted their works to be published in this book.

Wrocław, September 2012

Zofia Wilimowska

PART 1

MODELS OF INFORMATION MANAGEMENT
FOR BUSINESS ORGANIZATIONS

Peng WANG*, Cesar SANIN*,
Edward SZCZERBICKI**

ENHANCING SET OF EXPERIENCE KNOWLEDGE STRUCTURE (SOEKS) WITH A NEAREST NEIGHBOR ALGORITHM RELIE-F

In the past few decades, there has been a sharp growth in the amount of information. It is important for organizations to realize that sharing and managing knowledge has a great impact on business activities in keen market competitions. As knowledge representation, Set of Experience Knowledge Structure (SOEKS) or Decisional DNA provides features such as learning from experience, dealing with noisy and incomplete data, making precise decision and predicting. In this paper, a novel structure is introduced by combining the SOEKS with a feature selection model. This new structure can be used to extract useful knowledge from various sources such as web crawler, CVS files and among others. In addition, it compares with the extracted experiences in order to guides decision maker to make precise decisions. Furthermore, the combination of the SOEKS and the feature selection model has abilities to automatically calculate the most similar experience based on existing experiences. This function can be used for prediction purpose. Therefore, an experiment was implemented to test efficiency and effectiveness of this new structure.

1. INTRODUCTION

Knowledge is a fact to be aware of something from experience or education. Because Knowledge helps to solve problems including orientation, evaluation and reflection problems, it has played a remarkable role on modern social human activities. Knowledge Management (KM) consists of a scope of strategies and practices used in corporations to explore, represent and distribute knowledge. KM provides a way to extract and discover explicit and implicit knowledge from business practices. Organi-

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zations utilize KM to establishing knowledge repository and promoting communication between employees. This advent of rapidly growing information on the internet has resulted in a huge volume of data stored in various formats as plain files, multimedia data, Markup Language(ML) format and search queries among others [13], and this irresistible trend has posed opportunities to new techniques handling variously formatted information to extract useful knowledge. In fact, the majority of data has never been reused since it was made available on the internet. If this data collected from different fields is appropriately discovered and extracted, it can produce enormous hidden knowledge. Therefore, a simple, explicit and effective method which is able to extract useful knowledge from huge repositories, and be easily reused, has been demanded [5]. On the other hand, data mining or knowledge discovery in databases (KDD) is a mature technology that has been widely used to extract patterns from data repositories. It is an inclusive technique that includes statistics, Artificial intelligent (AI), machine learning, pattern discovery and database technologies. Hence, it can be applied to study data and find any trends or patterns in order to guide users to make it reusable [6]. Furthermore, SOEKS as a representation structure combines filtered information acquired from formal decision events to facilitate uncertain, implicit and incomplete data to help users make more precise decisions or predictions [12]. On this basis, this paper refines decisional DNA based web crawler [13] with data mining techniques. The RELIEF-F algorithm is a data mining technique that enhances capabilities of the SOEKS to make predictions in a more precise and efficient way. An experiment is introduced in this paper to compare with the traditional prediction method in Weka [1]. Furthermore, function of the SOEKS is tested by embedding linear regression method.

2. LITERATURE REVIEW

2.1. DATA MINING

Data Mining is defined as a process of discovering potentially useful, non-trivial, effective and ultimately meaningful patterns from existing data. It is a technique to solve problems by analysing or learning data. The data mining techniques extract useful and structured patterns. Once the patterns are found, they are used to inform future decision and make prediction. Many integrated and implicated algorithms are involved in the data mining technique. It has been comprehensively developed in many domains which include retail, Healthcare, finance, terrorism detection among others.

Weka was developed nearly two decades ago as a popular machine learning software. It is a comprehensive data mining application collecting machine-learning algorithms for data mining tasks [1]. It uses graphical user interfaces and visualization

utilities for data exploration and algorithm evaluation. There are many processes included such as data pre-processing, classification, regression, clustering, association rules and visualization. Because of its package based architecture, developed packages are flexibly loaded into the system. One of the most satisfying aspects of Weka is that the software has been incorporated into many other open-source projects [1]. In our experiment, the Weka will be used to compare with our new structure.

Many searches focus on feature selection within the area of application. It is a major component of the data mining prediction procedure. Three objectives of the feature selection are improving the prediction performance of the predictor, providing faster and cost-effective predictor, and providing a better understanding of the underlying process that generated data [4]. The RELIEF-F evaluation is one of the most valuable feature selection methods to evaluate the quality of the features because of its effectiveness and simplicity. It is based on the nearest neighbour paradigm to enhance the relevant level of different feature values between different concept values of example pairs [4]. Then, the features are looped and calculated ranks for a series of weight contributions. This weight ratio can finally be used in our structure to assist DDNA for prediction as Fig. 2.

Linear Regression, in statistical word, is an approach to analyse affection of a scale of the dependent variables to one or more explanatory variables. This regression uses linear predictor functions to model data and to find unknown parameters. It is the former type of regression to be extensively used in practical applications. In other words, if the model has been found, the prediction can be done without data source. As this result, it is passable to use it to predict a query when the query is out of range of the existing data source. We attempted embedding this model to enhancing our structure to adapt to different circumstances.

2.2. SET OF EXPERIENCE KNOWLEDGE STRUCTURE (SOEKS) AND DECISIONAL DNA

Web Data Mining is currently working with different types of knowledge. The idea behind it is to store and manage knowledge in some manners. In other words, mining web data is the process of storing, retrieving, distributing and sharing knowledge. However, web information is mostly unstructured or semi-structured in huge quantities. Thus, a technology which can be used to capture and store formal decisional events as explicit knowledge is necessary. The Set of Experience Knowledge Structure (SOEKS or shortly SOE) as a flexible and independent knowledge representation is a suitable tool for this task. Moreover, it has also been used to collect and store formal decisional events in an explicit manner [12]. Therefore, the SOEK can be a pattern based on existing and available knowledge offered by a formal decision event with dynamic structure. It can be expressed in XML or OWL as ontology in order to make it shareable and transportable [3, 8, 10].

The SOEKS is composed of variables, functions, constraints and rules [9]. The variables commonly use an attribute-value language to represent knowledge (i.e. by a vector of variables and values) [7]. It is the starting point for the SOEKS and the infrastructure of the SOE because they are the source of other components. Functions are made up of interactions of variables which include dependent variables and a set of input variables. On the other hand, according to the tasks of the decision event, functions are brought to reasoning optimal states. Therefore, this second component of the SOE establishes the relations between variables restricting experience on decision-making. Constraints are another factor of association amongst the variables. Though constraints are another way of functions, they have a different purpose. They limit the performance and possibility of a system and restrict the feasible solutions in a decision problem. Lastly, Rules are another form of expressing links among variables. They condition the relationships that operate the universe of variables. In the other words, they use the statements IF-THEN-ELSE to connect consequence with a condition.

Additionally, the SOEKS is structured in view of some important features of DNA. It imitates a gene in combining four nucleotides of DNA by integrating four components of the SOE, as a distinctive structure to adapt different needs. The components are not isolated between there four, but they connect each other. In the same way as a gene producing a phenotype, the SOE yields a value of decision with their elements. Each SOE can be categorised and acts as a gene in DNA [12]. A set of the SOE in a same category makes up of a decisional chromosome which stores decisional strategies for that category. After this, each module of chromosomes establishes an entire inference tool to offer a blue print of knowledge inside an organization [9].

A similarity metric is one of the fundamental concepts of Knowledge Discovery (KD). It provides an effective way to improve company's strategic and operational effectiveness and efficiency. Common similarity methods are measured by computing distance between two objects. This distance or similarity is used to deal with predictions, hypothesis testing and rule discovery [8, 11]. Therefore, the SOEKS introduces a geometrical function, an effective similarity metric, which individually calculates similarities among the variables, the functions, the constraints and the rules, to further produce a joint similarity value. It provides a scalar measure of the similarity between two objects. Those series of the similarities are ultimately used for prediction purpose [9]. Usually, the weight has to be calculated by expertise because its value dramatically affects a preciseness of the prediction [8].

2.3. OPTIMIZATION APPROACH TO DECISIONAL DNA APPLICATION

We first present a brief review of DDNA based a web crawler structure [13] (see Fig. 1). This architecture proved that web information is able to be converted into the Decisional DNA structure by four Macro Processes namely, Diagnosis, Prognosis, Solution and Knowledge Macro processes. The idea of this structure based on SOEKS

is to collect incomplete and noisy information by a web crawler in the diagnosis process. Afterwards, it transfers those crawled information into the DDNA structure for reusing and sharing purposes.
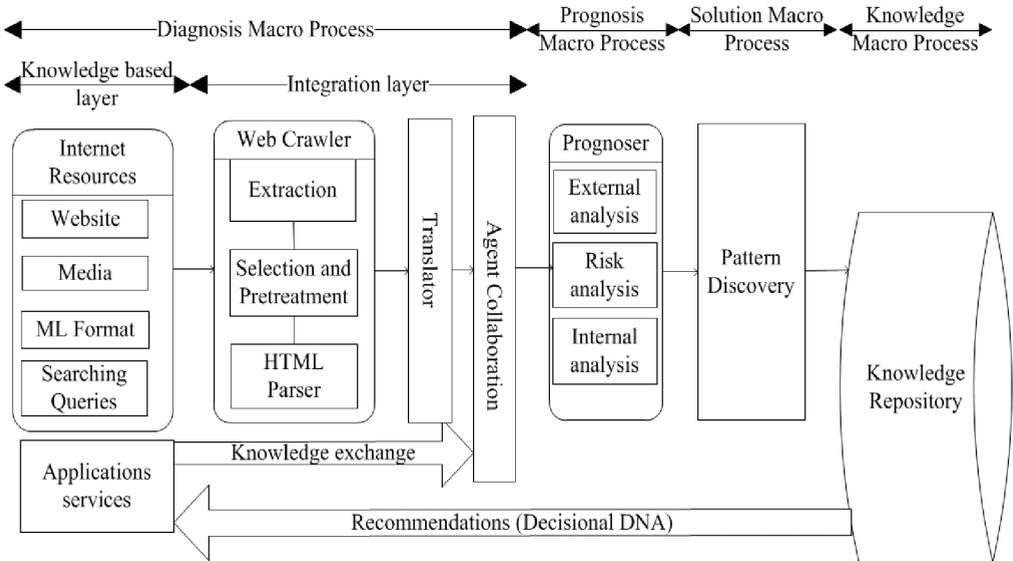
Fig. 1. Architecture of Decisional DNA-Based Web Crawler [13]

This paper is based on the previous research result in order to explore the functionality in the Prognosis, the Solution and the Knowledge Macro Processes in the decisional DNA. In addition, it indicates a new model to embed the RELIEF-F and the Ranking method into the Decisional DNA structure for automation and prediction procedures. This model offers many advantages. It can gain knowledge from different repositories. It stores different kind of information into Extensible Markup Language (XML) for sharing and transferring purposes. It not only share knowledge, but also assists in decision making and prediction process. This structure automatically produces a series of similarities between existing pares of experiences. Those similarities are commonly computed for predictions. It contains four main processes. They are diagnosis, prognosis, solution and knowledge macro processes.

In the Diagnosis, information can be collected from the website by a web crawler component or any repositories such as reading CSV files. And then, those collected information is integrated by a integration component for further analysis [13]. Once the Decisional DNA has been reached, a RELIEF-F evaluator and ranking method is used to rank the attributes in the Prognosis Macro Process. It generates a series of scores related to the attributes. Equation (1) is used to calculate the percentage of the weights for the SOEKS, and this equation illustrates how the system generates the

ratio R_j that should be allocated to the corresponding attribute. These numbers are between –1 and 1 and indicate how important the related attributes are. The vector O_j is the output given to the j-th attributes, and n is the total amount of the attributes. Therefore, according to equation 1, the outputs related to the attributes are calculated and exemplified in table 1. We designed an integration class to match those result to the weights associated with the same name of the DDNA variables.
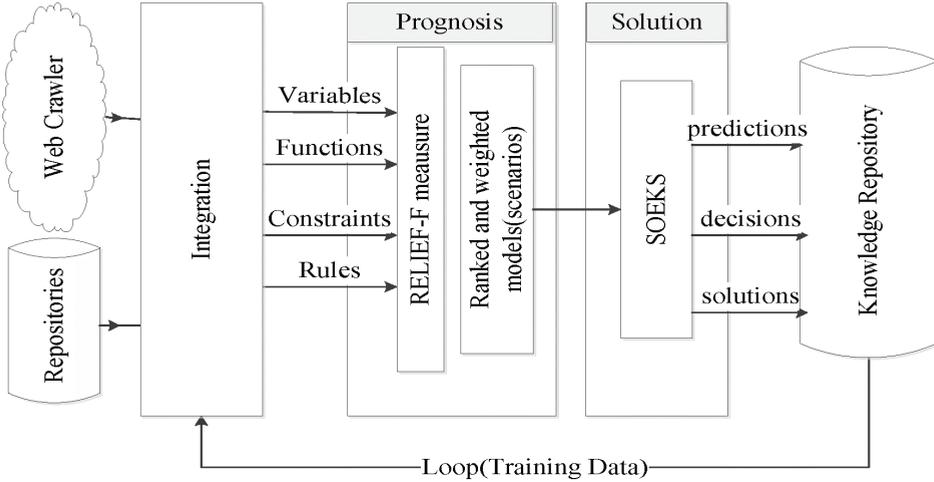
Fig. 2. Architecture of Decisional DNA-Based Data Mining

$$R_j = O_j \Big/ \left[2\sum_{j=1}^{n} O_j \right] \tag{1}$$

The SOEKS has been designed to deal with the most valuable asset: knowledge and it recognises patterns automatically in large multivariate data sets assisting decision making processes. As knowledge representation requirements, one of core functionalities of the SOEKS is to calculate differences between two data objects. In addition, a ranking of the result can be provided by choosing the best-matching objects [12]. It uses multidimensional scale for a similarity metric. For instance, the equation calculates distance d_{ij} between a pair of sets of Experience E_i and E_j. E_{ik} and E_{jk} are the k-th attribute of the sets of E_i and E_j. W_k is the weight given to the k-th attribute, and n is the number of variables on E_i. The similarity metric example for variables takes the following equation [8]:

$$s_v(E_i + E_j) = \sum_{k=1}^{n} \left[\frac{\left| E_{ik}^2 - E_{jk}^2 \right|}{\max\left(|E_{ij}|, |E_{jk}|\right)^2} \right]^{1/2} \quad \forall k \in E_i \wedge E_j \tag{2}$$

The SOEKS has different elements and each of them has its own characteristics, which can be separately used in computing similarity to compare with the query objects. The value of similarity is between 0 and 1. If an element has the highest similarity or zero value, the element will be the most similar or identical object and vice versa. It can be seen from equation 2 that the result is in some extent affected by how important attributes are (weight W_k). Experts may be able to decide the percentage of the weight rate. However, subjective mistakes can be made by human beings, and it will influence decision making. This is a great challenge to find a better automatic and objective way instead of the experts. The RELIEF-F measure is one of the best methods for the feature selection and it can be designed to automatically compute and rank the attributes [4]. Therefore, it will be suggested to assist the DDNA in our new structure for prediction. Similar but more complicated methods among functions, constraints and rules calculate similarity as in the variables above. The similarity feature makes the SOEKS comparable and classifiable, making it available for many different systems and technologies [8].

3. EXPERIMENT EVALUATION

In order to evaluate the preciseness and effectiveness of our new model, we implemented this structure in MacBook laptop with MAC system. We used the wine quality dataset [2] for testing purposes. This dataset contains 4898 records and 12 features. It was separated into two groups; one of 100 records for testing purposes and remaining 4798 records use for training of the SOEKS. The whole experiment is based on java language. In this experiment, our focus is on the performance of the SOEKS prediction.

Initially, the system demands data from various data sources such as web crawling or reading CSV files and among others. We generated a Prognoser class in the system with the responsibility of loading the data set. And then, it translates it into two types of instances. One is to evaluate attribute ranking and another is for SOEKS prediction. For the purposes, `ReliefFAttributeEval` class was created to implement RELIEF-F algorithm. Then, the CSV file was inputted into the system by using an array with two parameters. The parameter –*k* reveals number of nearest neighbours used to estimate attribute relevance. In our experiment, 3 nearest neighbours were used. Another parameter –*i* is used to tell the system the name of input the file. We used the `runEvaluator` to create the initial instance. The following code illustrates this process.

```
ReliefFAttributeEval relieffAttributeEvaluator = new
ReliefFAttributeEval();
String[]  args =  {''-K","3","-i","
C:\\winequality-white.csv"};
ReliefFAttributeEval.runEvaluator(relieffAttributeEvaluator,
   args);
```

Afterwards, weka produces a result as seen in figure 3. There are three columns generated; they are ranked weights, position of related attribute in dataset and names of attributes.

```
Ranked attributes:
 0.00483   2 volatile_acidity
 0.00451  11 alcohol
 0.0044    7 total_sulphur_dioxide
 0.00432   9 pH
 0.00429   1 fixed_acidity
 0.00423   6 free_sulphur_dioxide
 0.00356  10 sulphates
 0.00297   3 citric_acid
 0.00205   4 residual_sugar
 0.00174   8 density
 0.00171   5 chlorides


Selected attributes: 2, 11, 7, 9, 1, 6, 10, 3, 4, 8, 5 : 11
```

Fig. 3. Attribute Selection Output

According to the requirement of ranked weights discussed above, we need to collect this series of numbers to be used by SOEKS. Therefore, the system gained a series of number by invoking an array variable m_weights in the instance relieffAttributeEvaluator. After that, we used two loops to implement the equation 1 as follows:

```
double[]   rankedWeights = new
double[relieffAttributeEvaluator.m weights.length]; double
amount = 0;
for   (int i = 0;  i < relieffAttributeEvaluator.m
weights.length;
{
  if   (relieffAttributeEvaluator.m weights[i]   > 0)
   amount = amount + relieffAttributeEvaluator.m weights[i];
}
amount=2* amount;
for   (int i = 0;  i < relieffAttributeEvaluator.m
weights.length; {
  if   (relieffAttributeEvaluator.m weights[i]   > 0)   {
   rankedWeights[i]   = relieffAttributeEvaluator.m_weights[i]/
    amount; } else  {
     rankedWeights[i]   = 0;
  }
}
```

Eleven attributes were ranked and calculated weights according to a series of numbers produced by weka. Table 1 illustrates distributed weight for each attribute.

Table 1. Variable weights

Attributes	Output	Weight
volatile_acidity	0.00483	12.510%
alcohol	0.00451	11.681%
total sulfur dioxide	0.0044	11.396%
PH	0.00432	11.189%
fixed_acidity	0.00429	11.111%
free_sulfur_dioxide	0.00423	10.956%
sulPhates	0.00356	9.220%
citric_acid	0.00296	7.666%
residual_sugar	0.00205	5.310%
density	0.00175	4.533%
chlorides	0.00171	4.429%

Once the weights were created, the system will read the training dataset and the testing dataset for every experience in memory. In our experiment, there are 4798 training experiences loaded and 100 testing experiences loaded. As a result, two sets of SOEKS instances are created, as follows:

```
Prognoser prognosis = new Prognoser();
Vector<SOEKS> setOfTrainingExperience = prognosis
            .parseFromFile("./winequality-white.csv");
Vector<SOEKS> setOfTestingExperience = prognosis
            .parseFromFile("./wine-white-test1.csv");
```

After those two sets of experience are loaded in memory, the generated weights will be allocated to the related variables. A loop is used to assign collected weights to the variables of each experience of the training dataset. For example, for each training experience, `trainExpVars.get(0) .weight(weight)` is used to assigned weight to the variable in the SOEKS. And an equation, `double sim = Math.abs(trainExpVars.similarSOV(testVariables))`, is used to acquire similarities of comparing test and training experiences. The minimum value was output as prediction. This process is repeatedly executed untill all the predictions are found. The predictions are stored as XML files shown below.

```
<set_of_variabIes>
    <!-- Variables included in the model -->
  - <variable>
     <var_n a me >fixed_acidity</var_name>
     <var_type>NUMERICAL</var_type>
     <var_cvalue>6.9</var_cvalue>
     <var_evalue>6.9</var_evalue>
     <unit/>
     <internal>true</internal>
     <weight>0.004286464311431853</weight>
     <l_range>0.0</[_range>
```

```
    <u_range>0.0</u_range>
    <priority>0.0</priority>
</variable>
```

In the XML file, it has 12 variables of the SOEKS defined [12]. Each variable has a weight related. Therefore, this prediction is easy to be reused and transported in different systems. Additionally, it also has ability to be self-described according to the functionality of XML. Hence, knowledge will be expended and shared with different users.

Moreover, the DDNA is a representation structure that can learn or be trained by existing experience [12]. The quantity of sets of experience has a great impact on it. If the scope of existing experience is too short for the system to learn, the prediction will not be precise. However, the SOEKS is able to embed algorithm as function to enhance its ability. We tested this by introducing a linear regression function in our experiment to predict data when it is out of arrange of current experience. When the data was loaded into the SOEKS, the system executes linear regression classifier to calculate the model which has been saved as the function of the SOEKS (see below).

```
quality =" 0.061 *  fixed_acidity -1.9584 * volatile_acidity +
0.089 * residual sugar + 0.0028 *  free sulfur dioxide -
159.7935 * density +
0.6875 * pH + 0.665 * sulphates + 0.1924 * alcohol + 159.6391";

Prognoser.getFunctionFactor(quality,   queriedSOE);
```

Afterwards, each predicted object of the DDNA is produced based upon the linear regression function. The prediction has been successfully outputted by using `SOE.getSetOfFunctions() .get(0).value()`. When choosing this predicted set of experience for another prediction, those with better fitness value have a higher probability of being selected. In this case, the queried object is dynamically and iteratively produced to fill up different needs.

3.1. PERFORMANCE ANALYSIS

In this experiment, those two sets of experience, 4998 records in total, were separated into two CSV files and loading them took less than a second. Afterwards, the system spends 23 seconds to assess the percentage of variables' weights by the means of the weka module. Ultimately, the two groups of sets of experience consumed 6 seconds to evaluate 100 predictions from 4798 training experiences. The whole process spends in total 29 seconds. This experiment also proved that this new structure has several advantages. The SOEKS provided a semantic point of view over an XML approach in which it is able to deliver interesting benefits as its Ontology model allows inferring semantically new derived queries [10, 12]. It is commonly known that quality of predictions can be measured by using Mean Absolute Error (MAE) in statistics. In our experiment, we got a MAE score of 0.64 over 100 records. It presents a better

performance compare with another good prediction approach, decision stump, with a MAE score of 0.6675. We suggested that DDNA is able to be used for highly pre-ciseness and effective prediction. Figure 4 shows the predicted and observed absolute errors of training experience and queried instances between the decision stump and the DDNA approach. Both results fluctuated in scope of [–2, 3]. However, the prediction in DDNA has a smaller range of absolute error than in the decision stump. Hence, the DDNA indicates a highly precise performance of the SOEKS.
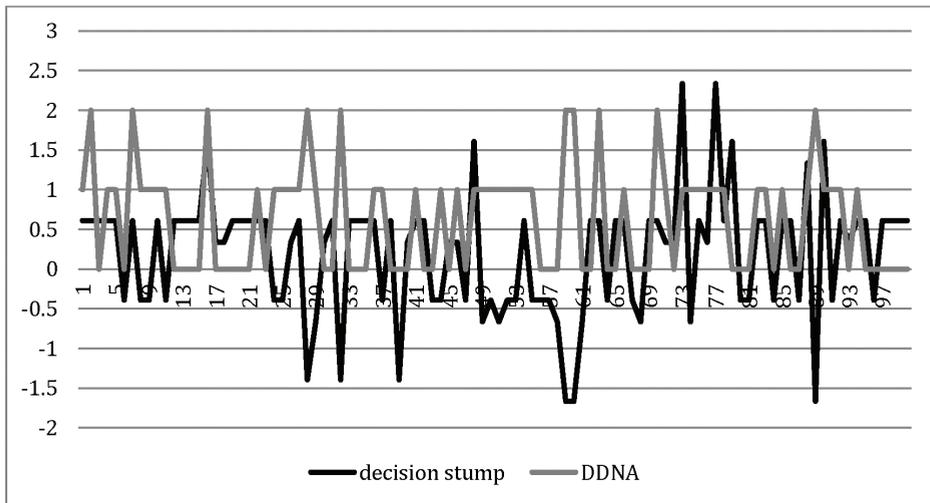
Fig.4. Predicted and experimental accuracy comparing with decision stump and DDNA

A difference from earlier works, including the two structures mentioned above, is our focus on discovering capabilities of prognosis, solution and knowledge macro processes in the SOEKS by integrating the RELIEF-F measure and linear regression into our struc-ture. The experiment demonstrates an implied and user-friendly measure for predictions.

4. CONCLUSION AND FUTURE WORK

The decisional DNA based data mining technique is a suitable and comprehensive tool for knowledge discovery. The enhancement of using RELIEF-F measure helps the SOEKS to automate the process of knowledge extraction. The empirical experiment also proved that this structure is an effective and efficient solution for prediction. Furthermore, as SOEKS is expressed in terms of variables, functions, constraints and rules, it is possible to integrate additional elements to adapt it to various circum-stances. Therefore, this structure can be efficiently and precisely used to explore knowledge from vast data sources. And, it assists users in making their data shareable,

transportable and easy understandable. Meanwhile, the highly intelligent functionality will be the key for user's information management.

This present work provides some important steps in forecasting direction, but it makes many assumptions that need to be studied in the future. First, the precision of weight estimation still has space to be improved. In addition, we still need to carry out more experiments to apply it into different domains. More extractions and inferences need to be experienced in order to assist organizations to make better decisions.

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TRANSFER AND ESTIMATION OF THE INFORMATION IN DISCRETE LIAISON CHANNELS

The use of the information for the decision of any problems is connected to necessity of its distribution, i.e. realization of processes of transfer and reception. Thus it is necessary to solve a problem of the coordination of a method of coding with characteristics of a liaison channel and also to provide protection of the transmitted information against possible distortions. The source of the information is an object or the subject inducing the information and representing it as the message, i.e. a sequence of signals. Transfer of the information is carried out due to use of a communication facility.

1. SOURCE OF INFORMATION

Communication facility – set of the devices providing transformation of the initial message from a source of the information in signals of a given physical nature, their transfer, reception and representation in the form convenient to the consumer [2, 3].

Communication facility there is a set: mail, the phone, radio, TV, computer networks and so forth. However at all variety of their concrete realization it is possible to allocate the general elements submitted in fig. 1.

The source of information (ИИ) gives out it as the initial message submitted by a sequence of initial signals. For the further transfer these signals will be transformed to signals of such physical nature which can be distributed in the given material carrier – the secondary message is formed

If it's necessary before transformation or during it coding of the initial message by the coder can be carried out. Coding (is more exact, initial coding) can be carried out directly by a source of the information, for example, the person at work on the transmitter with use of the Morse alphabet. Overlapping the coder with the converter is

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possible, for example, at work of the person behind the keyboard of the cable device or a computer it enters marks of natural language, and already they are translated by the device in codes which then are transferred.

Handicaps (noise)

ИИ → К → ПрдС → Liaison channel ← ПрмС ← ДК ← ПрИ

Protection against handicaps
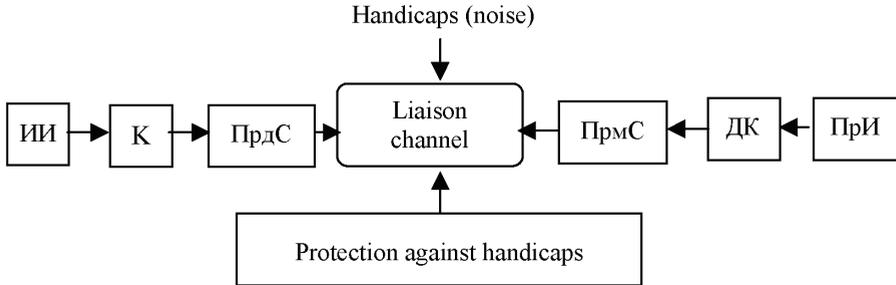
Fig. 1. General circuit of transfer of the information.
(ИИ – a source of the information; То – the coder; ПрдС – the transmitter of the message;
ДК – the decoder; At – the receiver of the information)

Direct transfer is carried out by the transmitter of secondary message (ПрдС). It initiates some non-stationary process providing distribution of signals in a liaison channel.

The liaison channel is a material environment, and also physical or other process by means of which transfer of the message is carried out, i.e. distribution of signals to space eventually.

Liaison channels depending on character of the signals transmitted on them are subdivided on discrete and analog. An example of the discrete channel is the computer network; analog – a telephone line and the radio channel.

Any real liaison channel is subject to external influences, and also in it there can be internal processes as a result of which transmitted signals are deformed and, hence, the information connected to them. Such influences refer to as noise. Sources of handicaps can be external, for example, so-called "buzz" from powerful consumers of electricity or the atmospheric phenomena, resulting to occurrence of infringements in a radio communication; simultaneous action of the several close located same sources (simultaneous conversation several the person). In handicaps can result and internal features of the given channel, for example, physical heterogeneity of the carrier; the parasitic phenomena in trunks; processes of attenuation of a signal in the communication line because of the big remoteness. If the level of handicaps appears is commensurable with intensity of bearing signal transfer of the information on the given channel appears in general impossible. However and at rather low levels of noise they can cause distortions of transmitted signals and, hence, partial loss of the information connected to them. Methods of protection against handicaps, for example, shielding of electric lines of connections exist and are applied; improvement of selectivity of the

reception device etc. In another way protection against handicaps is use of special methods of coding of the information, on what the question will be below.

After passage of the secondary message on a liaison channel it gets in reception device (ПрмС) where it will simultaneously be transformed to the form necessary for the further interpretation. If before transfer coding was applied, after reception the secondary message goes to decoder (ДК) and only then – to the consumer of the information (At). Thus the decoder can be combined with the converter (for example, the cable device or a computer) or with the receiver of the information (the radio operator accepting signals of the Morse alphabet and interpreting them).

Concept the communication line covers all elements submitted in fig. 1 circuits from a source up to the receiver of the information, i.e.: the communication line is set of a communication facility and a liaison channel by means of which transfer of the information from a source to the receiver is carried out.

Characteristics of any communication line are speed from which transfer of the message to it is possible, and also a degree of distortion of the message during transfer.

The discrete channel – a liaison channel used for transfer of discrete messages.

The simplified circuit of transfer of the information on a discrete liaison channel is submitted in fig. 2.
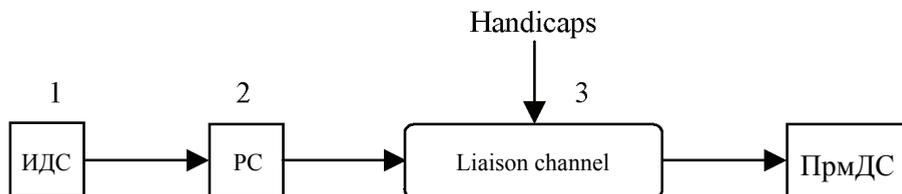
Fig. 2. Circuit of the discrete channel of transfer of the information.
(1 – the message in the alphabet {And}; 2 – codes of marks {And},
submitted by the alphabet entrance signals {and}; 3 – codes of marks {In},
submitted by the alphabet of accepted signals {b})

The source of discrete messages (ИДС) uses for representation of the information the initial alphabet $\{A\}$. The initial coder (PC) codes marks of the initial alphabet *n* elementary signals with the alphabet $\{a\}$. Action of handicaps during transfer can be, that the alphabet of accepted signals will differ from the alphabet of entrance signals both their number and characteristics – let it will be the alphabet $\{b\}$, containing m elementary signals. Discrepancy of alphabets of signals results to that on an exit of the channel there are such combinations of elementary signals which cannot be interpreted as codes of marks of the initial alphabet. In other words, the alphabet of the receiver of secondary message (ПрмДС) $\{B\}$ cannot coincide with the alphabet {A}. For simplicity it is possible to count, that the decoder of secondary signals is combined with the receiver.

The discrete channel is considered given if are known:

– time of transfer of one elementary signal τ;

– the initial alphabet of elementary signals $\{a\}$, i.e. all his marks a_i ($i = 1 \dots n$, where n – number of marks of the alphabet $\{a\}$);

– n values of probabilities of occurrence of elementary signals on an input(entrance) p (a_i); these probabilities refer to a priori (as they are defined not by properties of the channel, and a source of the message, are external in relation to the channel and the fact of transfer of the message);

– the alphabet of signals on an output of the channel $\{b\}$, all marks b_j ($j = 1 \dots m$, where m – number of marks of the alphabet $\{b\}$; generally $n \neq m$);

– values of conditional probabilities pa_i (b_j), each of which characterizes probability of occurrence on an output of the channel of a signal b_j provided that on an input the signal a_i was sent; as these probabilities are defined by properties of the channel of transfer, they refer to a posteriori; obviously, quantity of such probabilities equally $n \cdot m$:

$$M_k = \begin{vmatrix} p_{a_1}(b_1), & p_{a_1}(b_2), & \dots, & p_{a_1}(b_m) \\ p_{a_2}(b_1), & p_{a_2}(b_2), & \dots, & p_{a_2}(b_m) \\ \dots & & & \\ p_{a_n}(b_1), & p_{a_n}(b_2), & \dots, & p_{a_n}(b_m) \end{vmatrix}$$

It is obvious also, that for each line the condition of standardization is satisfied:

$$\sum_{j=1}^{m} p_{a_i}(b_j) = 1 (i = 1 \dots n)$$

All other characteristics of the discrete channel can be determined through the listed parameters.

The discrete channel is homogeneous if for any pair i and j the conditional probability pay (b_j) eventually does not change (i.e. influence of handicaps all time is identical).

The discrete channel is the channel without memory, if p (ai) a nd pai (bj) do not depend on a place of a mark in the initial message (there are no correlations of marks):

1. The source of the information is an object or the subject inducing the information and representing it as the message, i.e. a sequence of signals. Transfer of the information is carried out due to use of a communication facility.

2. If necessary before transformation or during it coding of the initial message by the coder can be carried out.

3. Direct transfer is carried out by the transmitter of the secondary message. It initiates some non-stationary process providing distribution of signals in a liaison channel.

4. The liaison Channel is a material environment, and also physical or other process by means of which transfer of the message is carried out.
5. The Discrete channel – a liaison channel used for transfer of discrete messages.

2. TRANSFER AND PROCESSING OF THE ECONOMIC AND FINANCIAL INFORMATION

The modern economy operates with huge volumes of the information which are simply incommensurable to what 5–7 years back were literally. It is caused by the increased streams of the information for last years. If still yesterday to the bookkeeper of firm to lead payment, it was necessary to arrive to bank and physically to bring in means for the settlement account today it can be made, not departing from a computer, having taken advantage of system Client–bank.

Economic information streams today make hundreds gigabyte only on Russia, and global in ten times more. And it only an example of a private concern.

To conduct successful economy, today it is not enough to have professional book-keepers and managers. Ways of operative granting of the information act in conditions of technocratic progress on the foreground. It means that in necessary time it is necessary for partners to give the necessary information. Besides speed of transfer of such information should be those, that during its transfer it is not obsolete. I.e. the partner in an ideal should receive your business-plan very quickly and to have time that it to process and answer.
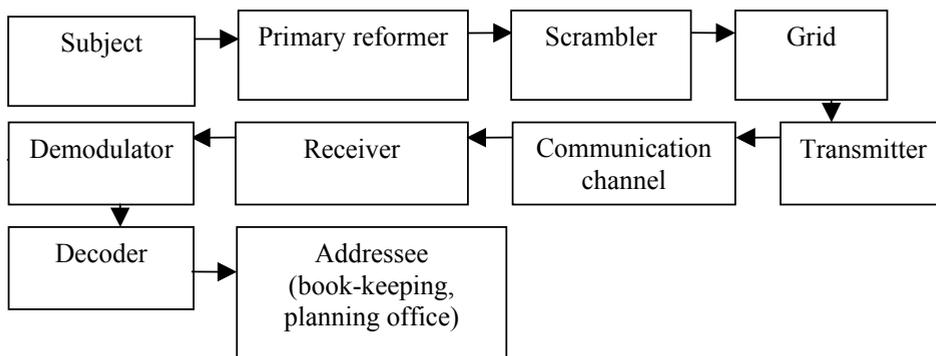
Fig. 3. The generalized model of system of transfer of the information

Messages are transferred from object to the addressee by means of set of means which form system of transfer of the information. How many exists methods of display of the information, it is possible to create and ways of its transfer so much. Therefore, speaking further about model of system of transfer of the information, we shall

mean it most a general view (fig. 3). To systems of transfer of the information concerns both mail, and TV, and the signal system [2–4].

As an example we shall consider work of single-channel system of transfer of the information, in which object – the manager of the organization, the addressee – accounts department, a planning section.

The initial converter is the personal computer. Then through a local network the signal gets to the addressee. Scrambler and the decoder in the given system are submitted in an implicit kind as with some assumptions Decoder, for example, it would be possible to count the manager, by a code – figures, and the decoder – elements of visual and emotional perception of the addressee. The general model of system of transfer of the information has conditional character. In the elementary liaison channels the receiver, the transmitter and the converter of capacity can be combined. For example: signals are transferred directly on the wire communication line.

3. MULTICHANNEL SYSTEM OF TRANSFER THE ECONOMIC AND FINANCIAL INFORMATION

For multichannel system of transfer the information devices of association and division of signals (fig. 4) are characteristic.
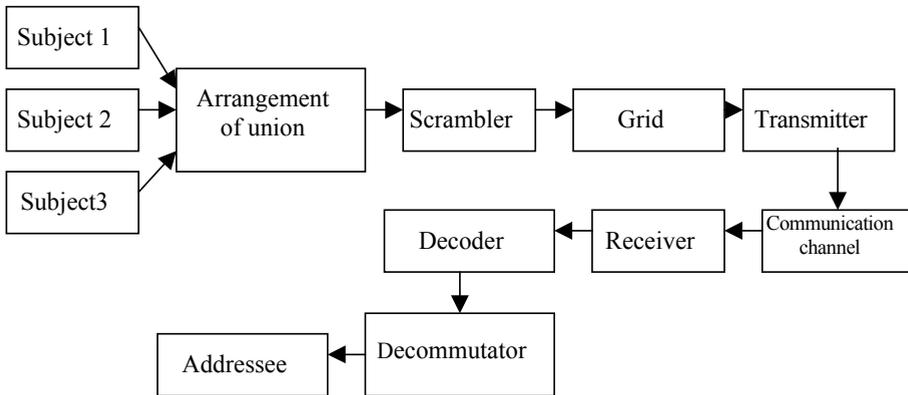
Fig. 4. Model of multichannel system of transfer of the information.

Let's assume, it is required to transfer the information on a condition of sales of any goods. Initial converters transfer the information in the electronic computer which processes it and then in the certain sequence transfers to the modulator. In this case ПЭВМ plays a role of the device of association and decoder.

The multichannel system supposes construction of coding devices up to the device of association, and decoding – after the device of division. However it should to try is

built how it is shown in fig. 5 that results in essential economy of the equipment. The multichannel system not necessarily means transfer of the information on several wires or on several bearing. It is not necessary to confuse a liaison channel and the communication line.

A liaison channel – set of the means intended for transfer of the information from object to the addressee; the communication line – environment (Wednesday) in which the signals bearing the information are distributed. For increase of throughput of communication lines on them transfer messages from several sources simultaneously. Such reception refers to as condensation. In this case messages from each source are transferred on the liaison channel, though the communication line at them general.
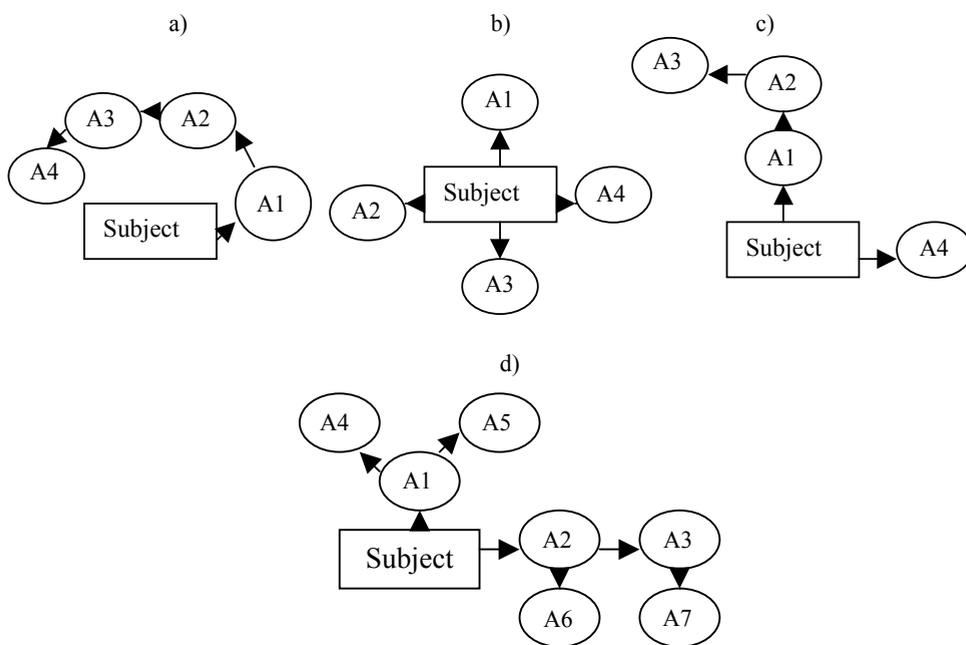
Fig. 5. Examples of the generalized structure of channel communication

It is quite possible, that one object can have some addressees, for example, in systems of telecontrol, and the telesignal system. Depending on structure of communication of object with addressees liaison channels can be: consecutive – the one-feeding communication line passes through each addressee A_1–A_5 (fig. 5a); radial – each of addressees A_1–A_5 is connected to object a separate one-feeding line; the number of the communication line is more or equally to two (fig. 5b); treelike – one-feeding lines directly do not incorporate to object, and are connected to it through a separate line; the number of communication lines is more or equally to three (fig. 5d).

4. PARAMETERS OF RELIABILITY OF PROCESSING
OF THE ECONOMIC INFORMATION

The mathematical model of a problem can be submitted as a standard set of parameters and the equations for the given conditions.

As from i a source of the information to j to the consumer of the information it is planned to transfer x_{ij} units of the information cost of transfer of the information will make size C_{ijx}.

Cost of the plan will be expressed by the double sum:

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} x_{ij}$$

System of restrictions of a problem transfer and processing of the information it is received from the following conditions of a problem:

− All files of the information should be transferred and processed on corresponding algorithms:

$$\sum_{j=1}^{n} x_{ij} = a_i \quad i = 1, 2, 3, ..., m;$$

− All information needs should be satisfied:

$$\sum_{i=1}^{m} x_{ij} = b_j \quad j = 1, 2, 3, ..., n.$$

Thus, the mathematical model of a problem of transfer and processing has the following kind.

To find the least value of linear function:

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} x_{ij}$$

At restrictions:

$$\sum_{j=1}^{n} x_{ij} = a_i , \quad i = 1, 2, ..., m,$$

$$\sum_{i=1}^{m} x_{ij} = b_j , \quad j = 1, 2, 3, ..., n,$$

$$x_{ij} > 0, \quad j = 1, 2, 3, ..., m; i = 1, 2, 3, ..., n.$$

In the considered model it is supposed, that total information resources are equal to total information needs:

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$

Such mathematical model of transfer and processing of the information refers to closed. Besides the above-stated parameters of efficiency, pay off also a parameter of a time of recovery of outlay capital expenses representing the attitude of capital expenses to economy of cost expenses:

$$T_{OK} = \frac{K_j - K_o}{\Delta C}$$

On set of the above-stated parameters get out the most effective variant of technological process of processing of the information.

5. TECHNOLOGICAL PROCESS OF PROCESSING OF THE ECONOMIC AND FINANCIAL INFORMATION

At the initial stage works "Definition of structure of the basic operations» and «Specification of structure of means of performance of operations" are carried out. As entrance documents for performance of these work materials of research, "Statement of a problem", "Technical project" and set of preliminary chosen means for operations of technological process serve. At stages of performance of these works receive the list of the basic operations, the description of technical operational characteristics of the chosen means and methods of work with them. The received data act as the initial data on an input of the following operation.

On the following operation the Choice of a quality monitoring and the means which are carrying out the control is carried out "On an input of operation acts universum a quality monitoring. As a result of performance of procedure receive the description of means and methods of performance of the control.

Further "Development of variants of circuits of technological process of data processing" is carried out. Entrance documents for the given operation are lists of the basic operations, characteristics of means and techniques of performance of the control. The purpose of performance of the given work is reception of block diagrams of several variants of technological processes.

The maintenance of the fifth operation is "the Estimation of technological processes on reliability, labor and to cost indexes". The given estimation is made on the basis of the technical project and design procedures of parameters. Result of performance of work is reception of tables of values of parameters.

As final operation the Choice of a variant of technological process and development of the technological documentation" serves Performance of the given work is based on the maintenance of the technical project, requirements GOST and OST on the techno-equipment design.

In result receive set technological and instruction cards.

Thus, generalizing all aforesaid, it is possible to draw the following conclusions:

1. The economic information is transferred from object to the addressee by means of set of the means forming system of transfer of the information. Thus the liaison channel concerns to means of transfer of the information, and the communication line represents environment (Wednesday) in which signals are distributed.

2. Depending on the communication line liaison channels are wire, radio, optical and hydro acoustic.

3. The more widely the strip of frequencies of a liaison channel, a lot of messages can be transferred on it simultaneously.

4. The width of a strip of frequencies directly depends on step-type behavior of the carrier. The more finely step-type behavior, the greater stream of the information can be transferred for one time unit.

From the point of view of an opportunity of simultaneous transfer of a maximum quantity of messages the most perspective is the optical liaison channel. Therefore it is necessary to carry out development in this direction.

6. MODULAR PRINCIPLE OF MODELING
OF ECONOMIC INFORMATION PROCESSES

Formation of an innovative policy at the enterprises of service last years in a new fashion. I define questions the organization, management of innovations and increases of efficiency work of workers the enterprises providing service of production. Their role in the present conditions appreciably changes and is connected to maintenance of optimum work the enterprises of service, rendering qualitative competitive services with the purpose of achievement worthy results in work. Problem of optimum control of economic process. Correctly planned and spent innovative activities at the enterprises of service of production are capable to make the organization more attractive to employees, clients, consumers.

Modern methods of management in economy yet in a sufficient measure take into account innovative tendencies in management of innovations. In particular, this use of various methods of mathematical modeling the specified economic processes.

For the decision there can be effective enough use of a method of management by dispersion V of expected expenses. The decision of a problem at modeling the eco-

nomic processes, giving low expected expenses, but showing significant instability, can appear not so desirable, as the decision showing the big degree of stability. Such case is considered by G. Markovits in his researches at the choice of a portfolio of securities. Stockbrokers frequently offer the buyers a wide range of actions, one of which are regarded by them as rather reliable, but bringing rather low incomes whereas others can give the high average income, possessing at the same time the big dispersion. The purpose of similar research is the instruction for each of set of levels of expected profits of that set of securities which minimizes a dispersion of the income.

The buyer is given to solve, what combination "level of the income" and "risk level" (min V) it prefers.

Let's assume, that the price does not depend from x_j and that are known a dispersion σ_j^2 of the price of the concrete goods p_j and of covariance σ_{jk} between two prices p_j and p_k. We shall put $\sigma_{jk} = \sigma_j \sigma_k Q_{jk}$, where the factor of correlation between two prices Q_{jk} satisfies to a condition $-1 \le Q_{jk} \le +1$. As all x_j commodity units are bought under the same price p_j, the dispersion of size x_j, p_j is equal $x_j^2 \sigma_j^2$, and covariance between x_j, p_j and $x_k p_k$ is equal $x_j x_k \sigma_{jk}$.

From here follows, that dispersion V_i of random variable E_i is defined by the square-law form:

$$V_i = M(C-E)^2 = \sum_{j=1}^{n} \sum_{j=1}^{n} x_j x_k \sigma_{jk} (\sigma_{jj} = \sigma_j^2$$

If, in particular, the prices strongly have correlation so for all practical purposes it is possible to count:

$$Q_{jk} = 1$$

and

$$\sigma_{jk} = \sigma_j \sigma_k$$

in this case it would be expedient to replace $V^{1/2}$ with linear expression limiting it

$$V^{1/2} \le x_1 \sigma_1 + x_2 \sigma_2 + ... + x_n \sigma_n$$

The equal-sign here takes place in that case, when all factors of correlation $Q_{jk} = 1$.

On the other hand, if all prices are independent:

$$V = x_1^2 \sigma_1^2 + x_2^2 \sigma_2^2 + ... + x_n^2 \sigma_n^2 \quad (Q_{jk} = 0)$$

7. CONTROL SYSTEM OF VARIOUS ECONOMIC OBJECTS

For creation of a control system by various economic objects demands presence of great volume of the information both on the object, and about his entrance and target variables. Distinguish two kinds of the information: aprioristic and current. The aprioristic information on object, his entrance and target variables, inwardnesses is necessary for construction of model on which the control system of this object will be created.

Before researches with use of mathematical models the various purposes are put. They define the processes proceeding in various time scales, and a degree of completeness mathematical model, its conformity to real object depend on the purposes for which this model is used.

Mathematical models of the first type have basically gnosiological character, from them close communication with methods of that concrete field of knowledge for which they are under construction is required. Models of such type are "inertial enough" in the development as reflect evolution in a concrete field of knowledge.

Mathematical models of the second type have information character and should correspond to specific goals on decision-making on management of object which they describe.

In the information models used directly for decision-making, the requirement of efficiency is one of the basic. It is caused by that at each influence it is necessary to take into account in model the valid changes during the real moment of time, having place in object, and external indignations on the basis of which management pays off. Such models are under construction on the basis of identification.

After conceptual model *C* is formulated and concepts a component of a environments are entered, the basic maintenance of elements of the applied theory of modeling for management of system will be made with components of *M* and *SS* and *DS* (criterion *K* is considered set), and transition from *M* to *SS* will make a static's of modeling, and transition from *M* to set *DS* with attraction of the information from component *SS* and *A* will make dynamics of modeling.

The task of a subject of the applied theory of modeling processes in system *S* is equivalent to the task of reproductive mathematical models. The maintenance of the applied theory of modeling covers two parts: basis of the theory including system of heuristic principles, received at generalization of available experience of modeling of complex objects in general, and the body of the theory containing heuristic rules machine realization concrete models of process functioning.

The offers of the theory concerning to components *M* and *SS* and *DS*, to separate realizations of process modeling refer to as precedents *Pr*. Generally reproductive mathematical model. Its basis, is set by set of principles, models determining desirable property (*SS* and *DS*) and other restrictions. Practical realization of model is reached

by performance a set of practical rules of realization of model which make a body of the applied theory of modeling.

Again using approximation x_{2j} by means of a broken line, we shall solve all over again a problem for value $k = 0$. It is easy to see, that it corresponds to case $E^* = +\infty$. If now gradually to increase k critical value $k = k_1$ at which the decision any more will not be optimum will be defined. It will lead to one or several changes of basis then the decision again becomes optimum. After that k again it is possible to increase up to achievement of new critical value $k = k_2$, etc.

Construction of modeling algorithm by a block principle allows to reduce expenses of time for modeling of system S as machine time in this case is not spent for viewing of repeating situations due to the organization of program modules. Besides the given circuit of modeling algorithm turns out easier, than in a case when modules are not allocated. Autonomy of procedures of sub module C_2 allows to carry out their parallel programming and debugging, and the described procedures can be standardized, based development a corresponding software of modeling systems.

The modular principle of realization of the mathematical model S formalized as the Q-circuit, is defined by the following positions. Let there is a $L\Phi$-phase multichannel Q-circuit lost-free with $L\mathit{И}$ entrance streams of applications. In each phase is present L_{jk}. Definition of distribution of a waiting time of applications in each phase and an idle time of each serving channel can be executed as follows.

As blocks of model OF_{MM} are considered: $m_{\mathit{И}}$ – blocks of sources of the applications, simulating $L\mathit{И}$ entrance streams; m_K – blocks of channels the service, simulating functioning channels; m_B – the block of interaction reflecting interrelation of all blocks of machine model OF_{MM}. Thus in a file of conditions the moments of receipt of applications, clearing of channels and the terminations of modeling are fixed.

The circuit of modeling algorithm for the given example can be made on the basis of the resulted mathematical expressions. In sub module C_2 should be stipulated three kinds of procedures are stipulated: $C_2' C_2'' C_2'''$.

The first procedure C_2' works at receipt of the application from any entrance stream, the second procedure C_2'' works at the moment of clearing the channel of any phase of service, except for last, the third procedure C_2''' works at clearing the channel of last phase, at the termination of service of the application by the Q-circuit.

Operators of procedures $C_2' C_2''$, C_2''' have corresponding parities. The operator C_{21}' defines an accessory of the application to one of $L\mathit{И}$ the entrance streams generated by the module of V. Operator C_{22}' checks, whether there is on the first phase a turn of free channels of service. If the turn is, management is transferred the operator C_{23}', otherwise – to the operator C_{24}'. The operator C_{23}' fixes the moment of receipt of the application in a file of turn of applications of the first phase.

The operator C'_{24} chooses number of the channel from a file of turn the channel the first phase, reducing its length on unit, calculates and fixes duration idle time of the channel, defines duration of service and transfers the new moment of clearing of the channel in a file of conditions.

Decision-making is beyond mathematical modeling and concerns to the competence of the responsible person to which the right of a final choice is given. It can be executed on the basis of use of methods which are developed in the theory of acceptance of optimum decisions. Operation is controlled action. Generally the purpose of operation is expressed in aspiration to achievement of extreme value of criterion of efficiency.

In real problems of production management it is necessary to take into account that some criteria have the big importance, than others. Such criteria can be ranged, that is to establish their relative importance and a priority. In similar conditions optimum it is necessary to count such decision, at which criterion, having the greatest priority is received with the maximal values.

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ESTIMATION OF DYNAMIC OBJECT ORIENTATION BASED ON ACCELERATION AND GYROSCOPIC MEASUREMENTS USING COMPLEMENTARY FILTERS

In this work problem of estimation of dynamic object orientation is presented. This problem is important in the point of view of human movement monitoring and analysis. In order to solve it processing data from accelerometers and gyroscope must be done. Unfortunately, mass produced low-cost sensing units are not perfect and some negative phenomena occurs in acquired data. One of the main problem in these devices is presence of noise in measurements. To cope with this problem complementary filter has been used. Complementary filter are used to combine signal from accelerometers and gyroscopes. Such approach can be helpful to suppress negative effects occurred in measurements. After a short introduction to the problem obtained results has been presented.

1. INTRODUCTION

Progress in wireless sensor networks (WSN), wearable sensors technology and methods of fusion them with information techniques makes basis for e.g. ubiquitous computing systems [3]. In such systems wireless sensor networks are composed of huge amount of low-cost, low-power sensing nodes and computational units. Sensing nodes are used to acquire measurements data and, with use of built-in wireless transceivers, transfer them through WSN to computational units. By computational units we mean *services* facilitating the access to one or more functionalities which are executed on remote servers. Services are used to build ubiquitous systems, with one or more functionalities, adjusted to user needs. Such systems operate in distributed computing environment in which wearable sensing nodes, computational units and wire-

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less sensor networks are connected. Combination of mentioned elements effects powerful tool to be used in various areas of application e.g. healthcare, sports, industry or entertainment [1], [4], [6–9], [15] and [16].

In this paper ubiquitous computing systems called SmartFit, designed to support endurance and technical training of either recreational and elite athletes, is presented. The main functional and non-functional features of designed system are discussed below.

The most important feature of the system is designed to support planning volume of for long-term endurance training. The aim of this training is maximization of sport performance. Because in all sports endurance training is required, this feature is universal and can be used in the same way by athletes in various sports. Only with one reservation: user (usually trainer) has to select physical exercises proper for athlete's sport game. The other functionality of the system is connected with endurance training monitoring. It is used to supervise correctness of the performed exercises, their right order and number of repetitions.

Another functionality of SmartFit system is designed to support technical training. On the contrary to endurance training, in this case, specific requirement for particular sport must be taken into account. Fortunately, architecture of SmartFit system provides mechanism for adding new functionalities supporting technical training of different sports easily.

2. STATE OF THE ART

Recently both commercial and research teams develop solutions for support both recreational and professional athletes. Such systems provide wireless measurements of vital signs and kinematic data as well as methods to process them in order to support training [10].

Polar offers either wearable devices for athletes and complex solutions for coaches [11]. Devices from the first group are composed of wrist worn watch and chest worn heart rate sensor. Depending on aims of the training, Polar provides equipment for fitness improvement or for sport performance maximization. These devices incorporate elements of motivational feedback i.e. generate beeps every time when certain amount of calories is burnt. The second group of Polar's products are designed for team sports. Besides heart rate monitors Polar offers software to monitor fitness capabilities of team. It is extremely useful in order to eliminate injuries and prevent overtraining. Moreover the software provides tools to optimize training intensities.

Suunto is another large company that offers wearable devices to support physical training both for amateurs and professionals [14]. Among others the company provides devices that generate personalized training plan. Based on results of user's training monitoring these devices are capable to make recommendations for training

volume i.e. the frequency, duration and intensity. Moreover proposed plan can be changed in order to adjust to user's current capabilities i.e. when user's activity level decrease.

MOPET is developing under research project [2]. It is wearable system to supervise a physical fitness activity. This system has features typical for systems offered commercially by Polar or Suunto. Additionally acquired data are used to build user's model. This model is periodically updated in order to produce exact prediction of user's performance. The results of model based prediction is apply to provide safety and healthy advices adapted to the user. MOPET has also implemented mechanisms that motivate the user by graphical and audio suggestions. For example in order to provide audio feedback system tells the user current speed and recommend increasing or decreasing current speed.

3. ARCHITECTURE OF SMARTFIT

Proposed architecture of SmartFit system (see Fig. 1) is composed of data acquisition units (BAN, PAN), data processing and supporting decision making units and presentation units.
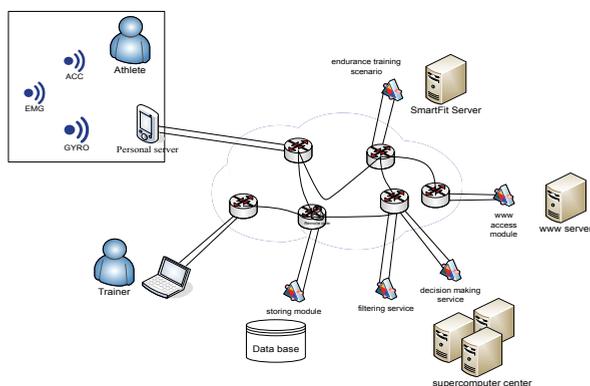
Fig. 1. Architecture of SmartFit

In the first group of units we can distinguish wireless sensor networks that are composed of sensing nodes. These nodes are placed on human body or his/her surroundings. Sensed data can be pre-processed on personal server such as smart phone or cellular phone and then results of computation are presented to the user or transmitted to the selected computational units through Internet. Personal server that runs on mobile device can be applied only to the tasks which are simple and they are not demanding complex calculations.

The second group of units are computational units which are executed on remote servers in order to process measurement data and to solve decision making problems. Selected computational units which are user and problem-oriented has been called scenarios. Implemented in SmartFit mechanisms allow to build such scenarios easily. Because of different nature of the sensed signal and problems, various data processing methods may be used in scenario. For example, in simple application only signal filtering algorithms are applied. Sophisticated problems may require applied mathematical models.

The last collection of units is used to present results of data processing and decision making such us visualization (e.g. charts) and reporting (e.g. tables).

4. PROBLEM DESCRIPTION

The problem, that the authors have to cope with, is calculation of the orientation of a sensor, which is located on a sportsman's chest. The mentioned device contains gyroscope and accelerometer. The authors would like to remove both noise from sensor signals and acceleration, which is caused by breathing. After that, calculate orientation of the sensor. In order to solve mentioned problems, some sets of data were gathered. Exemplary noise, which occurs in the signal is presented in figures below (Figs. 2–3):
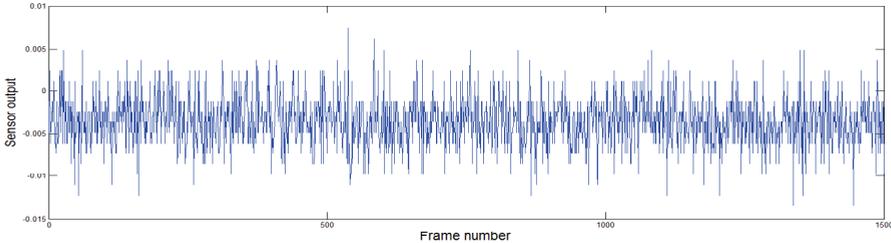
Fig. 2. Gyroscope signal in the time domain. The figure presents unprocessed signal,
which was not affected by motion
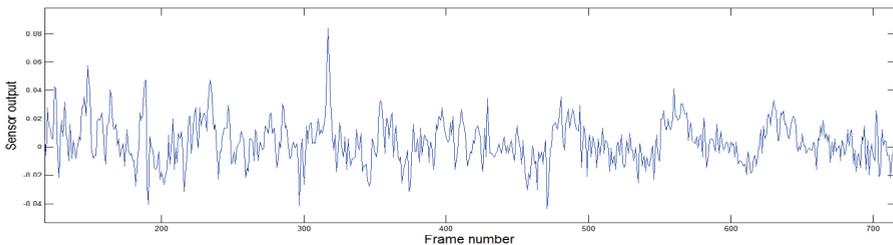
Fig. 3. Accelerometer signal in the time domain. The figure presents unprocessed signal,
which was additionally affected by sportsman breathing

The main purpose of the research is to check, which filter eliminates mentioned effects and makes it possible to calculate angles with the highest precision.

4.1. THE SOURCE OF THE PROBLEM

Measurements in the SmartFit system are collected from the gyroscope and the accelerometer, which are built into the sensor mounted to the sportsman's body. They have to work together, because of drift – a part of gyroscope nature. The accelerometer also has its faults. When the sportsman accelerates, there are considerable forces that act on the sensor and interfere accelerometer work, which returns true values only when the gravity is not disturbed. In the case of objects moving with a non-uniform motion, results given by the accelerometer are inaccurate. To solve the problem of tracking the athlete's body position, usage both above-mentioned sensors is necessary. They have their own disadvantages, but combined complement each other. The gyroscope is not suitable for measuring slow and long changes of athlete's body position, but it is insensitive to external forces acting on it and works well with short and clear position changes. On the other hand, the accelerometer suffers much the sportsman's speed changes (acceleration vibrations) but returns right values in longer periods of time. Such kind of combination requires the application of appropriate filters, which bind together the results of measurements obtained from both sensors. They are the subject of the further discussion.

5. FILTER OVERVIEW

There are few filters designed to combine values obtained from gyroscope and accelerometer. Some of them, are complex (i.e. Kalman filter), whereas others are much easier to understand and what is more important – to implement (complementary filters) [5], [12] and [13]. Often complexity goes hand in hand with the effectiveness, however, negligible differences often justify using of simpler solutions.
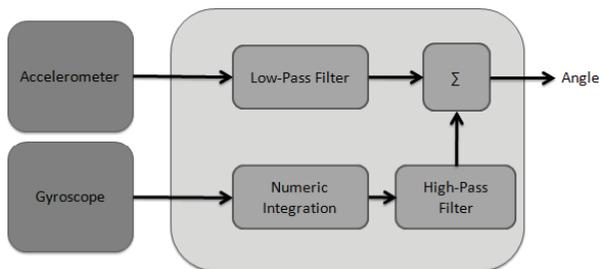
Fig. 4. Concept of first-order complementary filter

5.1. COMPLEMENTARY FILTER

In general gyroscope and accelerometer have different characteristics and they work well together. On this basis, the idea to create a filter that combines the advantages of both sensors and mitigate their defects appeared. The main idea is to pass gyroscope measurements through high-pass filter and simultaneously, accelerometer measurements through low-pass filter. Filters constructed from a combination of these two kinds are called complementary filters. In this paper first-order and second-order filters will be discussed.

5.2. FIRST-ORDER COMPLEMENTARY FILTER

The basic rule of first-order complementary filter is shown in Fig. 4. Numeric integration is used to change angular velocity, measured by gyroscope to angle, used to the further calculations. Data are obtained this way are passed through the High-Pass Filter and aggregated with data collected from accelerometer, passed through Low-Pass Filter.

Main idea of this filter can be written this way:

$$\alpha = a \cdot igyro + (1 - a) \cdot acc \,, \tag{1}$$

where *igyro* stands for integrated signal from gyroscope and *acc* stands for signal from accelerometer. It is worth to mention that *a* depends on the *Time Constant* (τ). This dependence is expressed by formula:

$$\tau = \frac{a \cdot looptime}{1 - a} \tag{2}$$

where *looptime* is a time between two measurements. The time constants is the relative duration of signal it will act on. For a high-pass filter, signals much shorter than the time constant will pass through, while longer wont.

5.3. SECOND-ORDER COMPLEMENTARY FILTER

The main principle is the same as in first-order complementary filter, but the algorithm is more complicated. The basic rule is shown in Fig. 5. Here we have the k constant to set, instead of τ in first-order complementary filter. In both cases, the only effective way to set those constants to their best values is to experiment with them.
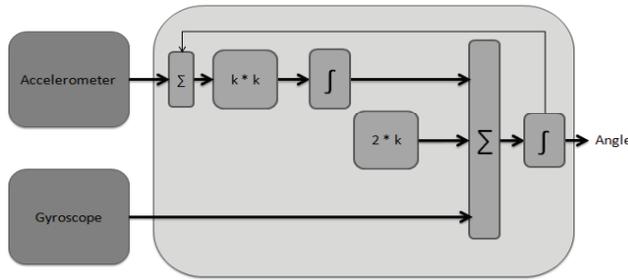
Fig. 5. Concept of second-order complementary filter

6. RESULTS

6.1. EXPERIMENT DESCRIPTION

In order to test quality of complementary filters, the authors decided to set up an experiment. At first, two software components were implemented:

a) An application for a mobile phone, which interacted with the wearable sensor,
b) A desktop application, which interacts with the mobile phone and save gathered data. It displayed id of currently received measurements on a screen.

During the experiment, the sportsman wore the sensor and was asked to repeat the same movement with different intensity. Simultaneously, a video camera recorded both the sportsman and the desktop application, which displayed analyzed measurement id. As a result each frame of the recording contained both a picture of the sportsman and id of measurement, so we were able to determine angle in any moment of the experiment (picture), and synchronize it with sensor data stream (id).

6.2. FILTERS EVALUATION

At the beginning, 20 frames of the recoding were selected randomly. After that, for each selected frame, angle was calculated using: the sportsman picture, an unfiltered accelerometer signal, the first-order and the second-order complementary filter. Quality of the filter was calculated using the following formula:

$$Q = \frac{1}{20}(\alpha_v - \alpha_c)^2 \tag{3}$$

where: α_v – angle calculated using the picture of the sportsman, α_c – angle calculated using tested filter.

6.3. DESCRIPTION OF THE RESULTS

During the experiment 1120 measurement frames were gathered. The raw measurements of gyroscope and accelerometer are presented in Fig. 6 and Fig. 7.
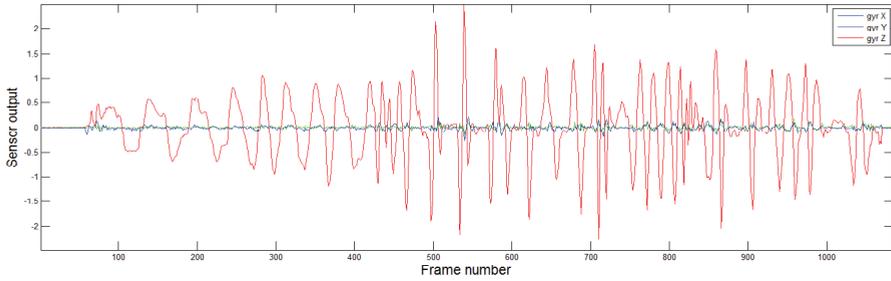
Fig. 6. A raw output of the gyroscope
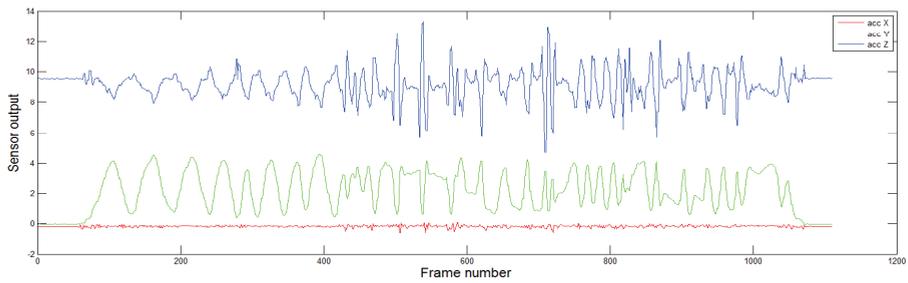
Fig. 7. A raw output of the accelerometer
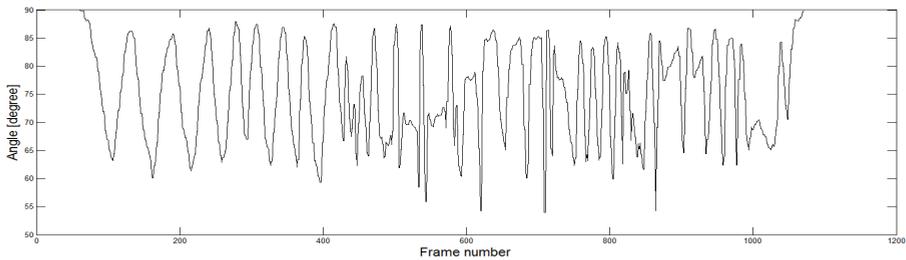
Fig. 8. Angle estimated based on formula 4

Based on the raw output, the angle can be calculated:

$$\alpha = atan\left(\frac{z_{acc}}{y_{acc}}\right) \tag{4}$$

where: y_{acc}, z_{acc} outputs of the accelerometers on z and y axis. Using formula (4), we obtained angles, which are shown in figure 8.

Using the same data, angle was estimated by the first and the second-order complementary filters (Figs. 9 and 10).
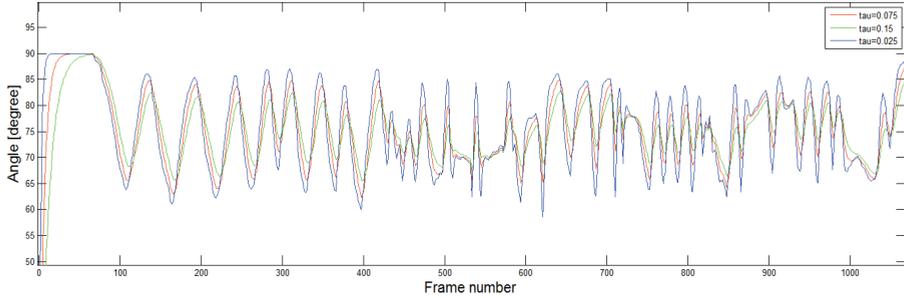
Fig. 9. Angle estimated based on the first-order complementary filters.
It is possible to observe, that the bigger τ parameter is, the lower sensitivity of the filter is

The last analyse was made for second order-complementary filters (Fig. 10).
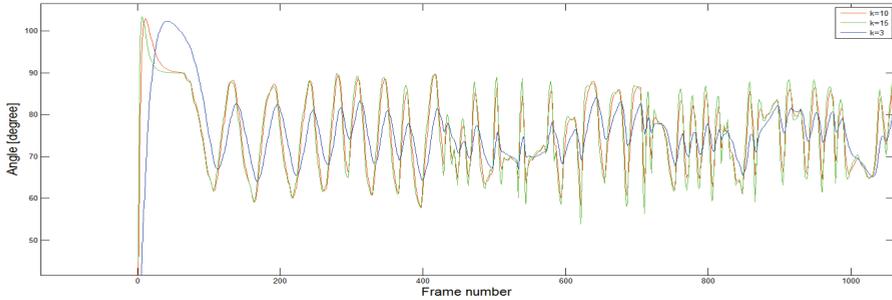
Fig. 10. Angle estimated based on second-order complementary filters.
It is possible to observe, that the bigger k parameter is, the bigger sensitivity of the filter is

Table 1. Mean squared error for each filters

Name of the filter	Q
Formula 1	64,44734
First order complementary ($\tau = 0,075$)	28,45902
First order complementary ($\tau = 0,15$)	23,87867
First order complementary ($\tau = 0,025$)	36,456
Secondary order complementary ($k = 10$)	42,67635
Secondary order complementary ($k = 15$)	45,92711
Secondary order complementary ($k = 3$)	25,19835

Finally, quality of those three methods were evaluated and compared. The results are presented in table 1.

6. SUMMARY

In general, results calculated using complementary filters were much more accurate than calculated using formula 1. However, it is difficult to set proper parameters for each filter. Depending on τ, value of mean squared error for first-order filter varied about 52%. In case of second-order filters, the difference was greater (approximately 82%). The complementary filters achieve better performance in estimation of orientation of dynamic object and were able to reduce noise more effective.

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ESTIMATION OF RELIABILITY CHARACTERISTICS IN A PRODUCTION SCHEDULING MODEL WITH THE RENEWAL THEORY APPLICATION – FIRST PART

In the paper a classical model of failures is considered in that successive failure-free times are supposed to have exponential distributions and are followed by exponentially distributed times of repairs. It is assumed that parameters of these distributions, in general, change with time. Basing on information about the number of failures in a number of periods of the same duration in the past, the method of estimation unknown parameters of the model based on renewal function is proposed. Next, predictions of the most important reliability characteristics are found using classical regression technique. In the paper the model of production system is presented, the production system is described by the processes routes of jobs, operation times of jobs, deadlines of jobs and butch sizes of jobs. We use the renewal function to estimate the reliability characteristics of the production system to reach the robust basic schedule. In the article theoretical description of the reliability characteristics are given, in the second article numerical example is attached.

1. INTRODUCTION

In a production process, reliability parameters depend on frequency of disturbances occurrence that cause changes in a basic schedule. The basic schedule becomes unrealizable after the disturbance has occurred. Any event which is possible to forecast should be planned in the basic schedule. The more changes in the basic schedule are the lower robustness of the schedule is. Cost of reorganization of the production schedule increases and time is wasted.

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A method of elaborating the robust basic schedule is searched. If the causes of disturbance are repeatable, probability theory can be applied to determine the time of the disturbance appearance in the next scheduling period. Analysis of historical data of a machine failures frequency, a number of the machine failures and data acquisition for prediction a future time of the machine failure are essential for elaborating the robust schedule.

In the literature the machine failure time are described by: Mean Time Between Failures (MTBF) and Mean Time To First Failure (MTTFF) and repair time is described by Mean Time of Repair (MTTR) [1,3]. To estimate unknown parameters of a distribution describing the MTBF following methods: empirical moments and Maximum Likelihood Principle were used [1, 3]. In this paper we propose the renewal theory application to estimate unknown parameters of the distribution. The frequency of the machine failure and time of the machine's repair are described by exponential distribution as it has been assumed that failure-free time of the machine does not depend on the previous work of the machine, and the repair time does not depend on time of previous repairing works of the machine.

Basing on literature review the paper is the answer for the need of searching of methods of distributions characteristics estimating. The problems of complementarities and reliability of historical data appear. The goal is to find a method that gives reliable values of exponential characteristics having historical data of the number of failure of parallel machines.

The schedule is robust if the disturbance will be predicted with success in other case if can be rearranged without decision maker participation. In the paper, having MTBF and MTTR, the robust schedule is elaborated by increasing the cycle time of the operation predicted to be disturbed in the time of repair.

2. A MODEL OF PRODUCTION MACHINE FAULURES

A production scheduling model of failures is considered in that successive failure-free times are supposed to have exponential distribution and are followed by exponentially distributed times of repairs. It is assumed that parameters of these distributions, in general, change with time. Basing on information about the number of failures in a number of periods of the same duration in the past, predictions of the reliability characteristics are searched.

Let us consider a classical model of failures in that successive periods of reliable work of a production system are followed by times of repair. Such the system, firstly, is observed on m successive time periods

$$[0, T), [T, 2T), ..., [(m-1)T, mT) \tag{1}$$

of the same durations, for which the information about numbers of detected failures is known. The prediction of system behavior is being built for the next period $[mT, (m + 1)T$ (Fig. 1).
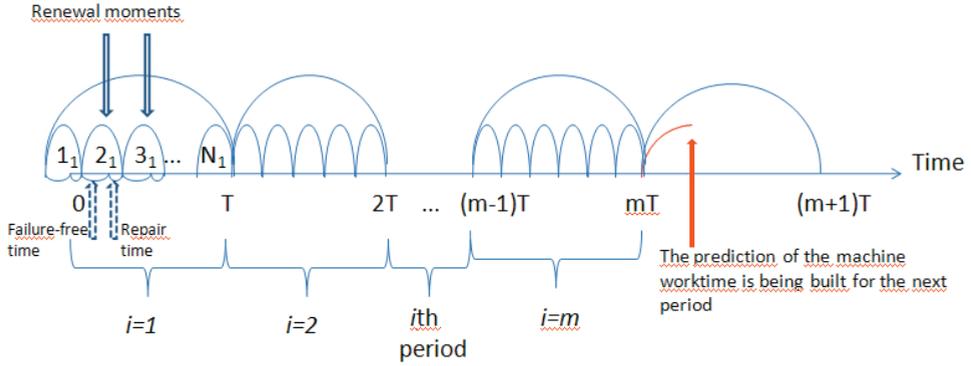
Fig. 1. The previous and future scheduling periods "windows"

We assume that failure-free times $X_{i,1}, ..., X_{i,N_i}$ in the i-th period $[(i − 1)T, iT)$, $i = 1, ..., m + 1$ have exponential distribution with PDF (= probability density function) $f_i(−)$ of the form

$$f_i(t) = \begin{cases} \mu_i \exp(-\mu_i t), & t > 0, \\ 0, & t \le 0, \end{cases} \tag{2}$$

where $\mu_i > 0$, thus parameters of the distribution depend on the number of period and are the same in each period separately. Here N_i denotes a random number of failures detected in $[(i − 1)T, iT)$. As it is well known [2]:

$$EX_{i,k} = \frac{1}{\mu_i}, \tag{3}$$

$$VarX_{i,k} = \mu_i^{-2} \tag{4}$$

where: $k = 1, ..., N_i$; $EX_{i,k}$ – the mean value of $X_{i,k}$; $VarX_{i,k}$ – the variance of $X_{i,k}$.

At the end of reliable work period $X_{i,k}$, as the failure occurs, a repair time $Y_{i,k}$ begins immediately and so on. Repair times $Y_{i,1}, ..., Y_{i,N_i}$ for $i = 1, ..., m + 1$ are supposed to be exponentially distributed with PDFs $g_i(\cdot)$ of the form [2]:

$$g_i(t) = \begin{cases} \lambda_i \exp(-\lambda_i t), & t > 0, \\ 0, & t \le 0, \end{cases} \tag{5}$$

$$EY_{i,k} = \lambda_i,$$
(6)

$$VarY_{i,k} = \lambda_i^{-2},$$
(7)

where: $\lambda_i > 0$ is known for $i = 1, ..., m+1$; $EY_{i,k}$ – the mean value of $Y_{i,k}$; $VarY_{i,k}$ – the variance of $Y_{i,k}$.

We take certain simplifying assumption that each new period of the form $[(i-1)T, iT)$, starts with the beginning of reliable work $X_{i,1}$, in other words we "delete" the residual repair time Y_{i-1,N_i} in the i-th period $[(i-1)T, iT)$. Thus, we can write

$$\sum_{k=1}^{N_i} Z_{i,k} = \sum_{k=1}^{N_i} \left(X_{i,k} + Y_{i,k} \right) \approx T, i = 1, ..., m+1.$$
(8)

Random variables $X_{i,k}$, $Y_{i,k}$, for $i = 1, ..., m+1$ and $k = 1, ..., N_i$ are supposed to be totally independent. So, the evolution of the system can be observed on successive cycles $Z_{i,k} = X_{i,k} + Y_{i,k}, i = 1, ..., m+1, k = 1, ..., N_i$ which are independent random variables with PDFs defined as follows:

$$h_i(t) = \int_0^t f_i(t-y)g_i(y)dy = \int_0^t g_i(t-y)f_i(y)dy, t > 0$$
(9)

and DFs (=distribution functions) of the form

$$H_i(t) = \int_0^t h_i(y)dy, t > 0.$$
(10)

2.1. RENEWAL-THEORY APPROACH

To estimate the reliability characteristics of distribution the method based on the renewal theory is proposed. Assume that if $\xi_1, \xi_2, ...$ are nonnegative and independent random variables with the same distribution function $B(t)$; then the following stochastic process:

$$v(t) = \max\left\{ n \in N : \sum_{i=1}^n \xi_i < t \right\}, t \geq 0$$
(11)

is called a *renewal process* generated by random variables $\xi_1, \xi_2, ...$ with *renewal moments* $t_n = \sum_{i=1}^n \xi_i, n = 1, 2, ...$

Thus, the value $\nu(t)$, at fixed moment t, is equal to the maximum number of random variables ξ_i which sum does not exceed t. For example: for $\xi_i = \{3, 2, 2, 4\}$, $t_n = \{3, 5, 7, 11\}$ and the values $\nu(t)$, at fixed moments t are presented in Tab. 1.

Table 1. The values $\nu(t)$, at fixed moments t

t	1	2	3	4	5	6	7	8	9	10	11	12
$\nu(t)$	0	0	0	1	1	2	2	3	3	3	3	4

Let us assume that a single time period a "time window" consists of a certain random number of "complete" cycles (failure-free time of a machine work and time of repair). Failure-free times and time of repair in the single "time window" have the same distributions (distributions can be different in successive time periods).

Thus, in the given scheduling period single cycles create a simple renewal process with the renewal function of the form:

$$U(t) = \sum_{n=1}^{\infty} H^{n*}(t), t > 0 \tag{12}$$

where H is a distribution function of a "complete" cycle and successive convolutions $H^{n*}(t)$ are defined as follows:

$$H^{1*}(t) = H(t), \quad H^{n*}(t) = \int_0^t H^{(n-1)*}(t-y) dH(y), \quad n \geq 2. \tag{13}$$

Let $N(t)$ be a random number of failures in time period $[0, t)$ (we assume that the time period belongs to the first scheduling "time window"). From the properties of renewal process (see e.g. [6]) follows that the first and the second moments of $N(t)$ can be expressed by means of convolutions of distribution function $H_1(t)$. Indeed, we have (compare (8)):

$$EN(t) = \sum_{n=1}^{\infty} H_1^{n*}(t) = U(t) \tag{14}$$

$$VarN(t) = 2\sum_{n=1}^{\infty} n H_1^{n*}(t) - U(t) - U^2(t) = \Psi(t) - U(t) - U^2(t) \tag{15}$$

$$\Psi(t) = 2\sum_{n=1}^{\infty} n H_1^{n*}(t) \tag{16}$$

and $U(t)$ is the renewal function generated by distribution function H_1 of the cycle „inside" the first "time window" $[0, T)$.

Estimation of unknown parameters of the distribution defining failure-free time of the machine will be based on evaluation the functions $EN(t)$ and $VarN(t)$ and comparing them to mean $\bar{x}_1$ and variance $s_1^2(x)$ of the number of failures detected in the first scheduling period for certain number of k machines working simultaneously beginning with $t = 0$. Next, from the system of equations:

$$\begin{cases} EN(t) = \bar{x}_1 \\ VarN(t) = s_1^2(x) \end{cases} \tag{17}$$

the estimators of the unknown parameters of the failure-free time distribution H_1 in the first „time window" $[0, T)$ will be found. Introduce Laplace–Stieltjes transforms of appropriate functions in the following way:

$$\begin{cases} \hat{\Phi}_1(s) = \int_0^\infty e^{-st} dEN(t) = \int_0^\infty e^{-st} dU(t) \tag{18} \\[2mm] \hat{\Phi}_2(s) = \int_0^\infty e^{-st} d\Psi(t) \tag{19} \end{cases}$$

Since the transform of a sum equals the sum of transforms (of the same type), and the transform of a convolution equals the product of transforms then, applying (12) in (18), we obtain:

$$\hat{\Phi}_1(s) = \int_0^\infty e^{-st} d\left(\sum_{n=1}^\infty H_1^{n*}(t)\right) = \sum_{n=1}^\infty \left(\hat{H}_1(s)\right)^n = \frac{\hat{H}_1(s)}{1 - \hat{H}_1(s)}, \tag{20}$$

where $\hat{H}_1(s) = \int_0^\infty e^{-st} dH_1(t) = \int_0^\infty e^{-st} h_1(t)$, and $h_1(t)$ is the probability density function of the distribution $H_1(t)$.

Similarly we can prove that

$$\Phi_2(s) = 2\sum_{n=1}^\infty n\left(\hat{H}_1(s)\right)^n = 2\hat{H}_1(s) \cdot \sum_{n=1}^\infty n\left(\hat{H}_1(s)\right)^{n-1} = \frac{2\hat{H}_1(s)}{\left(1 - \hat{H}_1(s)\right)^2}. \tag{21}$$

In the equation (21) we use the differentiation of power series term by term:

$$\sum_{n=1}^{\infty} nq^{n-1} = \left(\sum_{n=1}^{\infty} q^n\right)' = \left(\frac{q}{1-q}\right)' = \frac{1}{(1-q)^2}, \quad |q| < 1. \tag{22}$$

Now we can invert the right sides of (20) and (21) on argument s in order to find the original functions of the left sides that is the functions $U(t)$ and $\Psi(t)$. The inversion of the Laplace or the Laplace–Stieltjes transform we can execute using "Mathematica" packet. When we have $U(t)$ and $\Psi(t)$ we also find $EN(t)$, $VarN(t)$ from (14) and (15), and from the equations (17) we estimate values of unknown parameters. If the distribution function of the failure free time of the machine has two parameters (e.g. normal, gamma, Weibull distributions) it is necessary to solve the whole system of equations (17). It is enough to use the first equation of the system (17) if the distribution has only one parameter (e.g. exponential distribution).

For the next periods for $i = 2, ..., m$ we use the same algorithm for estimating the unknown parameters. Having parameters for the periods for $i = 1, ..., m$ we use the classical regression to predict parameters for the $(m+1)$-th period. Having parameters for the $(m+1)$-th period, we estimate Mean Time Between Failures $EX_{m+1,k}$ and the mean value of the machine repair $EY_{m+1,k}$.

3. A MODEL OF PRODUCTION SYSTEM

Having $EX_{i,k}$ and $EY_{i,k}$ we build the predictive schedule for a production system with input data: a number of jobs J, $j = 1, 2, ..., J$ have to be executed on a number of machines W, $w = 1, 2, ..., W$. Each job consists of a number of operations V_j, $v_j = 1, 2, ..., V_j$; a_{w, v_j} denotes as an execution time of operation v_j of job j on machine w. The execution times of operations a_{w, v_j} are predefined in a Matrix of Operations' Times $MOT = [a_{w, v_j}]^-$ (24). A production route is described in the Matrix of Processes' Routes $MPR = [b_{w, v_j}]$ (23); b_{w, v_j} states as a priority of execution of operation v_j on machine w. Dead line d_j of execution of job j is predefined and described in Vector of Due Dates $VDD = [d_j]$ (25). Butch size of job j is predefined and described in Vector of Butch Size $VBS = [s_j]$ (26).

$$MPR = \begin{bmatrix} b_{v_1,1}, b_{v_1,2}, \ldots, b_{v_1,w}, \ldots, b_{v_1,W} \\ \vdots \qquad \ldots \\ b_{v_j,1}, b_{v_j,2}, \ldots, b_{v_j,w}, \ldots, b_{v_j,W} \\ \vdots \qquad \ldots \\ b_{v_J,1}, b_{v_J,2}, \ldots, b_{v_J,w}, \ldots, b_{v_J,W} \end{bmatrix} \quad MOT = \begin{bmatrix} a_{v_1,1}, a_{v_1,2}, \ldots, a_{v_1,w}, \ldots, a_{v_1,W} \\ \vdots \qquad \ldots \\ a_{v_j,1}, a_{v_j,2}, \ldots, a_{v_j,w}, \ldots, a_{v_j,W} \\ \vdots \qquad \ldots \\ a_{v_J,1}, a_{v_J,2}, \ldots, a_{v_J,w}, \ldots, a_{v_J,W} \end{bmatrix} \qquad (23,24)$$

$$VDD = \begin{bmatrix} d_1, d_2, \ldots, d_j, \ldots, d_J \end{bmatrix} \qquad (25)$$

$$VBS = \begin{bmatrix} s_1, s_2, \ldots, s_j, \ldots, s_J \end{bmatrix} \qquad (26)$$

The predictive schedule is generated using Enterprise Dynamics (ED) software. ED can simulate the operation of the production system in which work of each machine is described by two parameters: Mean Time Between Failure (MTBF) and Mean Time of Repair (MTTR). The predictive schedule is generated by increasing the duration time of an operation predicted to be disturbed. The best predictive schedule is selected according to the minimum value of the scalar objective function $f(x)$. The first sub-criterion is a makespan minimization $fs_1(x) = C_{max} \to \min$, second one is a due date of production jobs $fs_2(x) = T \to \min$.

$$f(x) = \sum_{o=1}^{O} fs_o(x) \cdot w_o \qquad (27)$$

$$fs_o(x) = f_o(x) \Big/ f_o(x^*) \qquad (28)$$

where: $fs_o(x)$ – the scalar function; o – the number of scalar function, $o = 1,2$, $f_o(x^*)$ – the Maxima value of the scalar function o; w_o – the priority of the scalar function o.

$$C_{max} = \max\left[tz_{V_j}\right] \qquad (29)$$

$$T = \sum_{j=1}^{J} \left[0, |D_j|\right] \quad \text{where} \quad \begin{cases} 0, & if \quad d_j - tz_{V_j} \geq 0 \\ |D_j|, & if \quad d_j - tz_{V_j} < 0 \end{cases} \qquad (30)$$

where: tz_{V_j} – the end time of the operation V_j of the job j, d_j – the deadline of execution of the job j, D_j – the delay of execution of the job j.

We need to obtain the no delayed robust schedule with minimum makespan.

4. A PREDICTIVE SCHEDULING

Having MTBF and MTTR the robust schedule is elaborated by increasing cycle time of the operation predicted to be disturbed, by the time of repair. The job's operation will be disturbed if the start time of the operation $tr_{V_j} \leq MTTF$ and the end time of the operation $tz_{V_j} \geq MTTF$. The start time of the operation will be delayed if $tr_{V_j} = MTTF$ and $tz_{V_j} \geq MTTF$, the ending time of the operation will be delayed if $tr_{V_j} \leq MTTF$ and $tz_{V_j} \geq MTTF$:

$$tr_{V_j^*} = tr_{V_j} + MTTR \tag{31}$$

$$tz_{V_j^*} = tz_{V_j} + MTTR \tag{32}$$

where: $tr_{V_j^*}$ – the start time ($tz_{V_j^*}$ – the end time) of the operation V_j of the job j after the disturbance has occurred.

4. CONCLUSION

In the paper the classical model of failures is considered in that successive failure-free times are supposed to have exponential distributions and are followed by exponentially distributed times of repairs. It is assumed that parameters of these distributions, in general, change with time. Basing on information about the number of failures in a number of periods of the same duration in the past, renewal function to estimate unknown parameters of the MTBF is proposed. In the paper the model of production system is presented, the production system is described by the processes routes of jobs, operation times of jobs, deadlines of jobs and butch sizes of jobs. We use the renewal function to estimate the reliability characteristics of the production system to reach the robust basic schedule.

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ESTIMATION OF RELIABILITY CHARACTERISTICS IN A PRODUCTION SCHEDULING MODEL WITH THE RENEWAL THEORY APPLICATION – SECOND PART, NUMERICAL EXAMPLE

In the paper a classical model of failures is considered in that successive failure-free times are supposed to have exponential distributions and are followed by exponentially distributed times of repairs. It is assumed that parameters of these distributions, in general, change with time. Basing on information about the number of failures in a number of periods of the same duration in the past, the method of estimation of unknown parameters of the model based on renewal function is proposed. The Mean Time Between Failures of the "bottle neck" in the production system with parallel machines is predicted. The "bottle neck" is a machine which works constantly. The "bottle neck's" failure time should be introduce to the basic schedule and thus make in robust. According to the Theory of Constrains (TOC) it is crucial to identify a constraint of the system – the "bottle neck" and break the constraint in continuous process of improving quality of the production. In the paper we propose the method for exploitation of the system's constraint – how to maximize utilization of the "bottle neck", how to plan its technical inspections.

1. PROBLEM FORMULATION

There is a wide variety of constraints (like: an activity duration, release and due dates, precedence constraints, transfer and set-up times, resource availabilities, and resource sharing) which may influence scheduling. In addition, preference constraints characterize the quality of scheduling decisions. These preferences are re-

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lated to: due dates, the productivity, the frequency of tool changes, inventories level, overtime, etc. Various techniques of optimizations give satisfying solution – a basic schedule.

The quality of the basic schedule can be deteriorated by a wide variety of disturbances coming from internal and external enviroments. These disturbances are related to: machine can be broken, material and rough products suppliers may deliver overdue, jobs priority may change, some jobs may be phased out from production and some may be introduced into production. We search for techniques of preventing the disturbances.

In the above context two problems are considered:

Problem 1. The production system consists of a set of parallel machines and the set of production orders already accepted for realization. A machine which is used in 100% is a "bottle neck". If a machine breaks down rescheduling interval needs to be done. The "bottle neck" is the production system's constraint. Following this thought, the producer's question is: is it possible to predict the "bottle neck" failure time to generate robust schedule? According to the Theory of Constrains (TOC) it is crucial to identify a constraint of the system and break the constraint in continuous process of improving quality of the production [2].

We propose the TOC approach to improve the quality of the schedule by doing five steps:

1. Identification of the production system's constraint – the "bottle neck" of the production system.
2. Exploitation of the system's constraint – failure time of the "bottle neck" needs to be predicted to insert "time window" in a schedule at the time of failure, and to plan the technical inspection of the "bottle neck" to get the highest productivity within the existing capacity limitations.
3. Subordination of everything else to above decision – the organization of the production enterprise e.g. schedules of materials', tools' delivery, maintenance workers should be adjust to the decision made above.
4. Elevation of the production system's with constraint – to evaluate the schedule we use a criterion of stability of the schedule. As in [1] we assume that the predictive schedule needs to be stable in the solution space and objective function space. It is assumed that the schedule is stable in the solution space, if start times of operations will not change after the machine has failed. The schedule is stable in the space of the objective function if the quality of evaluation criteria: date of completion of tasks, due date of jobs, do not deteriorate after the disturbance has appeared. We search for predictive schedule with maximum stability.
5. After completion of operations related to the maintenance of the machine we back to step 1, to identify another disturbance can affect the schedule but do not allow inertia to cause the system's constraint.

Problem 2. Basing on historical data about number of failures of a set of parallel machines that contains the "bottle neck", the Mean Time Between Failures (MTBF) of the "bottle neck" can be estimated for the following scheduling period. We assumed that the failure-free time of the "bottle neck" is described by exponential distribution. The question is how to estimate a parameter of the Exponential distribution and predict the failure time of the "bottle neck" making assumption that the machines are in the middle of life cycle predefined by a producer. At the beginning of the machine's live cycle the machine "wears out" the most, then the process is slower and slower, at the end of the live cycle the frequency of the machine's failure starts to increase.

We propose the renewal theory approach to estimate MTBF of the "bottle neck". According to more classical methods, such an approach is a non-standard one in this type of problems. Moreover, the renewal theory gives a possibility for estimating unknown parameters of the time distribution basing only on the observed number of failures in successive periods.

2. A MODEL OF PRODUCTION MACHINE FAULURES

There are 7 scheduling periods "time windows", each takes 100 hours, $T = 100$. 3 jobs have to be executed on 5 machines.

The operations' times $a_{v_j,w}$ ($v_j = 1, 2, 3$, $w = 1, 2, ..., 5$) are described in minutes in MOT. The processes routes are described in MPR. In the matrices MOT (1) and MPR (2) a number of row represents a number of job j, a number of column states as a number of machine w. Let us consider the first operation of the first job $v_1 = 1_1$, the operation is produced on machine $w = 2$ and the duration time equals $a_{1,2} = 4$ minutes. The dead lines and butch sizes of jobs are described in VDD and VBS. In vectors, a number of column states as a number of job j. For example, the dead line of job $j = 1$ equals 450 minutes (3), the butch size of job $j = 1$ equals 40 (4).

$$MOT = \begin{bmatrix} 3,4,1,1,3 \\ 3,2,1,2,0 \\ 4,0,1,1,2 \end{bmatrix}, \quad MPR = \begin{bmatrix} 2,1,5,3,4,6,7 \\ 2,4,1,3,0,0,0 \\ 2,0,1,3,4,7,8 \end{bmatrix}, \quad (1), (2)$$

$$VDD = \begin{bmatrix} 450, 550, 650 \end{bmatrix}, \quad (3)$$

$$VBS = \begin{bmatrix} 40, 50, 60 \end{bmatrix}. \quad (4)$$

The machines start work at time $t = 0$. Historical data of the number of failures of machine j are as follows:

Table 1. Data of the number of failures of parallel machine j

		The number of scheduling period i						
		1	2	3	4	5	6	7
		Duration of the scheduling period i [in hours]						
		[0, 100)	[100, 200)	[200, 300)	[300, 400)	[400, 500)	[500, 600)	[600, 700)
		The number of failures of machine j						
j	1	4	5	7	9	9	12	11
	2	3	6	7	7	8	10	11
	3	2	6	6	8	9	7	10
	4	3	4	6	7	9	10	9
	5	3	3	7	6	7	11	10
$\bar{x}$		3	4.8	6.6	7.4	8.4	10	10.2

Let we assume that a failure-free time has exponential distribution with unknown parameter $\mu > 0$, thus we have:

$$F(t) = 1 - e^{-\mu t}, t > 0, \quad f(t) = \mu\, e^{-\mu_i t},\ \ t > 0, \tag{5}$$

From the equation (9, first article), we have:

$$h(t) = \int_0^t f(t-y)g(y)dy = \int_0^t \mu e^{-\mu\,(t-y)}\lambda e^{-\lambda\,y}dy = \frac{\lambda\mu}{\mu - \lambda}\left(e^{-\lambda\,t} - e^{-\mu\,t}\right), t > 0 \tag{6}$$

where λ is a known parameter of exponential time of repair. Parameters λ and μ, in general, are different in different scheduling periods. The Laplace–Stieltjes transform of the DF (=distribution function) H of has the form:

$$\hat{H}(s) = \int_0^\infty e^{-st}dH(t) = \int_0^\infty e^{-st}h(t)\,dt = \frac{\lambda\mu}{\mu - \lambda}\int_0^\infty e^{-st}\left(e^{-\lambda t} - e^{-\mu t}\right)dt = \frac{\lambda\mu}{(s+\lambda)(s+\mu)}. \tag{7}$$

The right side of equation (7) is also a consequence of the fact, that the single cycle is a sum of failure-free time of machine work and a repair time (independent), thus the distribution of the cycle is given by a Laplace–Stielties convolution of distributions F and G. And, the transform of the convolution $H * G$ equals the product of transforms. It means: since $H(t) = F(t) \cdot G(t)$ then $\hat{H}(s) = \hat{F}(s) * \hat{G}(s)$, and we have:

$$\hat{F}(s) = \int_0^\infty e^{-st} f(t)dt = \int_0^\infty e^{-st} \mu e^{-\mu t}dt = \frac{\mu}{s+\mu}. \tag{8}$$

Similarly we have:

$$\hat{G}(s) = \frac{\mu}{s+\mu}, \text{ therefore we have } \hat{H}(s) = \frac{\lambda\mu}{(s+\lambda)(s+\mu)}. \tag{9}$$

From the equation (20, first article) we obtain:

$$\hat{\Phi}_1(s) = \frac{\hat{H}_1(s)}{1 - \hat{H}_1(s)} = \frac{\lambda\mu}{(s+\lambda)(s+\mu)} \Big/ \left(1 - \frac{\lambda\mu}{(s+\lambda)(s+\mu)}\right) = \frac{\lambda\mu}{s(s+\lambda+\mu)}. \qquad (10)$$

Inverting the right sides of (10) on the argument *s* we find the original functions:

$$EN(t) = U(t) = \frac{\lambda\mu}{(\lambda+\mu)^2}\left(e^{-(\lambda+\mu)t} - 1 + (\lambda+\mu)t\right) \qquad (11)$$

Let us assume that the successive scheduling periods have repairing times [in minutes] with exponential distributions with parameters λ_i :

Table 2. Data of average repairing times in scheduling period *i*

The scheduling period *i*	1	2	3	4	5	6	7
λ_i	1.5	1.2	0.8	0.7	0.5	0.4	0.3

For the successive scheduling periods we solve the equation:

$$\frac{\lambda_i\mu_i}{(\lambda_i + \mu_i)^2}\left(e^{-(\lambda_i+\mu_i)T} - 1 + (\lambda_i + \mu_i)T\right) = \bar{x}_i, \qquad (12)$$

where *T* = 100 [hours] (is a duration time of the scheduling period).

Substituting known values of: λ_i and $\bar{x}_i$ we estimate μ_i for successive periods, for example, for the first scheduling period $i = 1$, we have:

$$\frac{1.5\mu_1}{(1.5+\mu_1)^2}\left(e^{-(1.5+\mu_1)\cdot 100} - 1 + (1.5+\mu_1)\cdot 100\right) = 3. \qquad (13)$$

Thus $\mu_1 = -1.49$ or $\mu_1 = 0.0308177$. Since $\mu_1 > 0$ we take $\mu_1 = 0.0308177$. Similarly, in successive periods we have:

$$\mu_2 = 0.05042,\ \mu_3 = 0.0728442,\ \mu_4 = 0.083945,$$

$$\mu_5 = 0.103015,\ \mu_6 = 0.13673,\ \mu_7 = 0.159811.$$

In successive periods mean failure-free times of the machine (the reciprocal of the parameter μ_i in the Exponential distribution) equal:

$$EX_1 = 32.4489,\ EX_2 = 19.8334,\ EX_3 = 13.7279,$$

$$EX_4 = 11.9126,\ EX_5 = 9.70732,\ EX_6 = 7.31368,\ EX_7 = 6.25739.$$

We have noticed, that at the beginning of the machine's live cycle the machine "wears out" the most, then the process is slower and slower, this is a natural phenomenon.

Having parameters μ_i for the periods $i = 1, ..., 7$ we use the classical regression to predict a parameter for period $i = 8$, and we have $\mu_8 = 0.148847$. The function of the regression is as follows: $\mu_i = 0.00683031 + 0.017752 \cdot i$. Mean Time Between Failures in period $i = 8$ equals $EX_8 = 6.71832$.

Having parameters λ_i for the periods $i = 1, ..., 7$ we use the classical regression to predict parameters for period $i = 8$, and we have $\lambda_8 = 0.235952$. The function of the regression is as follows: $\mu_i = -0.63 \ln(i) = 1.546$. Mean Time of Repair in the period $i = 8$ equals $EY_8 = 0.235952$.

3. A MODEL OF PRODUCTION SYSTEM

The production system described by *MOT*, *MPP*, *VDD* and *VBS* is modeled in the Enterprise Dynamics (ED). The model consists of the following objects: 3 products, 3 sources, 7 machines, 8 queues, 3 Gantt initializes, Gantt chart, 2 tables and sink. The layout of objectives is presented in Fig. 1.
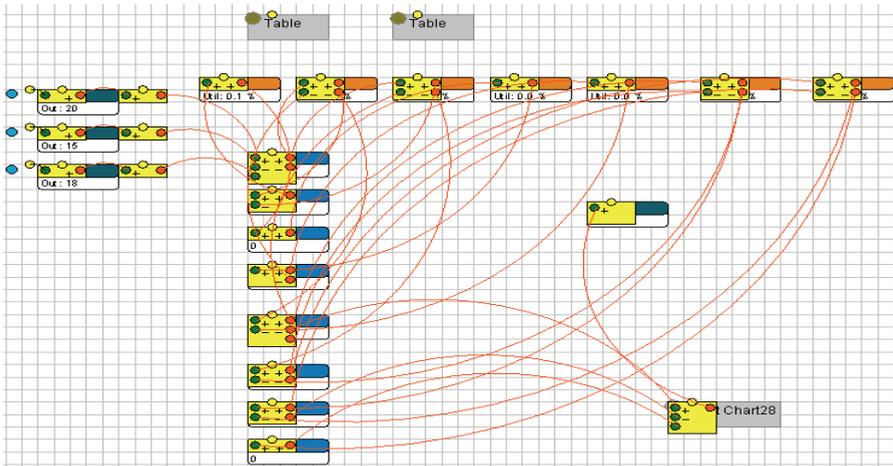
Fig. 1. The layout of the production system modeled in ED

The butch sizes are introduced in the *Source* objects. *Inter-arrival times* of the products equal 10 minutes, and *Time till first product* will have been arrived equals 10 minutes. In the first *Source* object, in position *Trigger on exit* the commend: *setlabel([P],1,i)* is applied to set the number 1 to the first type of products.

Input data of processes' routes are introduced in Table 1 (Fig. 2), operations' times are introduced in Table 2 (Fig.3). Jobs are served on the Q*ueue* object according to the priority rules: First In First Out (FIFO), Last in First Out (LIFO), RANDOM. *Queues* objectives are used to dispatch the product through appropriate channel described in "Table of Processes' Routes". A number of *Queue* represents a number of operation. Let us consider the operation 5 of product 1, the *Queue* 5 sends the product 1 through the first channel to the machine 3. In the *Queue* objectives in position *Sent to* the command: *Processes Routes(label([P],first(c)),label([O],first(c)))* is given. In the *Queue* 5 objective in position *Trigger on entry* the command: *setlabel([O], 5, i)* is applied to set the operation number 5 before operation 5 is executed on the appropriate machine. The *capacity* of the *Queue* objectives equals 10.

In the *Machine's* object the cycle time is read from "Table of Cycle Times". In the *Machine's* object on position *Cycle Times* the command: *Cycle Times(label([P], first(c), label([O], first(c)))* is applied. Let us consider the operation 5 of product 1, the cycle time equals 5 units of time.

Fig. 2. The processes' routes defined in ED

Fig. 3. The operations' times defined in ED

4. SIMULATION OF THE PRODUCTION

After doing the first simulation for RANDOM priority rule, the "bottle neck" is identified. MTBF and MTTR are defined for the "bottle neck" – the machine 1. Since

the input data of operations' times and jobs' deadlines are defined in minutes (1, 3), and input data of failure-free times and repair times are defined in hours (Table 1 and 2) so $EX_8 = 6.71832$ and $EY_8 = 0.235952$ are multiplied by 60 minutes and the MTBF = 402 [minutes], and MTTR = 14 [minutes].

The predictive schedule includes the information of predicted time of failure and the cycle time of operation predicted to be disturbed is increased (Figs. 4–6). Extending the duration of the operation shifts all operations following the operation disturbed.
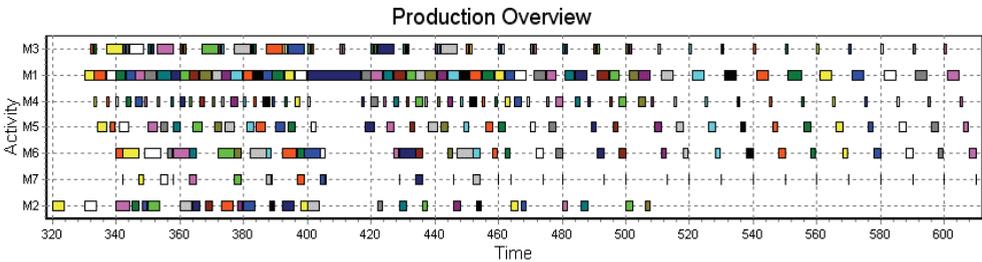
Fig. 4. Gantt chart generated for priority rule RANDOM
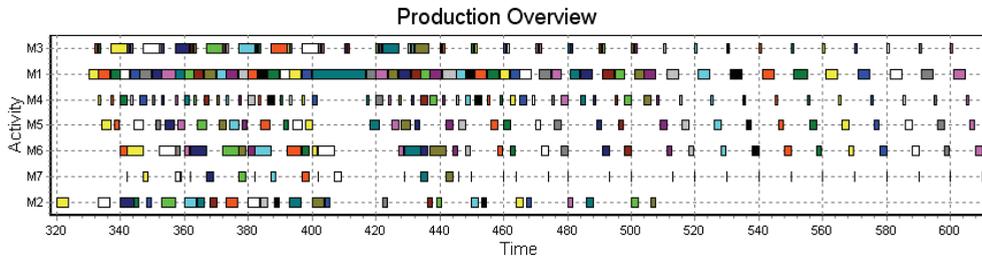
Fig. 5. Gantt chart generated for priority rule FIFO
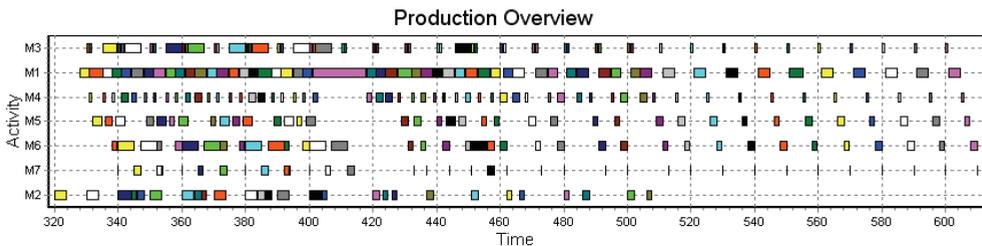
Fig. 6. Gantt chart generated for priority rule LIFO

Time till machine 1 is the "bottle neck" for RANDOM, FIFO priority rules equals 469 minutes, for LIFO priority rule equals 460 minutes. Applying Gantt chart for LIFO priority rule, the disturbance which occures after 460 minutes for the operation has no strong influence on the schedule. After rescheduling after some period the new schedule reseambles the previous determinned.

Table 3. The end time of the operation V_j of the job j
after doing simulations for various priority rules

	RANDOM	FIFO	LIFO
tz_{V_1}	454	444	458
tz_{V_2}	508	508	508
tz_{V_3}	610	610	610

The end time of the operation V_j of the job j after doing simulations for various priority rules are presented in Table 3. Criteria: Makespan C_{max}, due date of production jobs T are used to evaluate the solutions. C_{max} and T of predicted schedules generated using FIFO, LIFO, RANDOM rules are presented in Table 4. Values of the scalar function for weights of the criteria: $w_1 = 0{,}4$ i $w_2 = 0{,}6$, respectively are presented in Table 3. The best predictive schedule is selected according to the minimum value of the scalar objective function $f(x)$. The best schedule is generated for FIFO rule.

Table 4. C_{max}, T and $f(x)$ of predicted schedules
generated using FIFO, LIFO, RANDOM rules

	C_{max}	T	$f(x)$
LIFO	610	8	$= (8/8) \cdot 0.6 + (610/610) \cdot 0.4 = 1$
FIFO	610	0	$= (0/0) \cdot 0.6 + (610/610) \cdot 0.4 = 0.4$
RANDOM	610	4	$= (4/8) \cdot 0.6 + (610/610) \cdot 0.4 = 0.7$

5. SIMULATION OF THE PRODUCTION

In the paper we propose the method for exploitation of the system's constraint – how to maximize utilization of the "bottle neck", how to plan its technical inspections before its failure occurs. The method of estimation unknown parameters of the model is based on renewal function, and input data of the method is the number of failures in the number of periods of the same duration in the past.

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APPLICATION OF GENERALIZED PARAMETER METHOD TO SUPPORT NOTEBOOK PURCHASING DECISIONS IN ORGANIZATIONS

All organizations, especially big companies, face purchasing decisions to buy certain number of notebooks, often hundreds or thousands, with best business features and within a budget. Highly competitive business of notebook computers and their diversity make the process difficult. Therefore, using the decision support methods in evaluating and selecting alternatives is the beneficial way to help the IT managers choose the best products. Several such methods exist and are applied in enterprises, but their main disadvantage is that single composite measures for each alternative are determined. The objective of this work is to analyze possibility of applying a method that calculates additional measures for groups of criteria. We propose Generalized Parameter Method to support notebook purchasing decisions and present a case study to demonstrate that it can be very useful during the notebook selection process in organizations.

1. INTRODUCTION

The decision to purchase one product rather than another becomes more difficult as the number of product attributes under consideration increases. Having to simultaneously evaluate numerous product alternatives can further complicate this decision process. Notebook personal computers are a good example of a product whose many attributes (e.g. price, performance, display type) and many vendors make direct comparisons difficult. Notebook selection (supplier selection problem in general) is especially important and risky in big organizations as many items are ordered, even hundreds or thousands, and the equipment is uniform (the configuration of all items is the same). Wrong decision can have significant impact on the budget or on the comfort and efficiency of users.

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This problem is a multi-criteria decision making (MCDM) problem and is addressed by many methods that support the decision maker. The decision analysis is used increasingly for a wide variety of decisions and both, the number of published applications and the rate of publication have increased [18]. These multiple criteria decision techniques cover a broad range of decisions, with such application areas as energy, technology, finance, manufacturing, medical, military and others [11]. They have been applied in a variety of information technology areas, including notebook or PDA selection [10] [14] [2] [13]. In this paper, an attempt has been made to propose a multi criteria decision-making method appropriate in cases when the attributes can be grouped, and to demonstrate its use to evaluate quality of notebooks purchased in big quantities by organizations.

2. MULTIPLE CRITERIA DECISION MAKING

Various approaches have been developed and adopted to help individuals or organizations to make the best decision. MCDM refers to a situation of finding the best alternative from all of the feasible alternatives in the presence of multiple decision criteria attributed to these alternatives. In order to evaluate the alternatives, the decision maker has to collect all considered alternatives and their attributes (criteria), organize them into a matrix and fill the matrix with values that describe the alternatives according to the criteria. The procedure usually involves some data preprocessing, like normalization, and assigning weights to the attributes. The evaluation is obtained by combining values for each alternative with a function ("method") to get rid of the worst alternatives or to get the final preference ranking.

The attributes used by a decision maker depend on his/her personal characteristics or attitude, the object of the decision and its complexity, time left to decide, importance etc. Each attribute is assigned a target – the direction of desired changes (lower or higher values are better). The values of the attributes can be quantitative or qualitative objective numbers or utility function subjective measures, etc. Qualitative criteria estimates are generally based on previous experiences or expert opinions and transformed to a suitable scale, like Likert's or 0 to 5, etc.

The attributes are in different units, so the composite values of these attributes often cannot be calculated nor interpreted in this form. Prior to analysis, the attribute values for each alternative must be converted into a standardized form using a normalization method. The normalization of the decision matrix is crucial to ensure that the data are consistent and coherent. Several normalization procedures can be used, but all ensure the same target direction regardless of the nature of the attribute. The maximum difference is usually mapped to 1 and the minimal difference is mapped to 0 (assuming the values are linear between these points) [8], [13].

Some of the criteria (attributes) are usually more important than the others, therefore attribute weights are often introduced to the decision matrix. The decision maker has to make judgments that provide ratio-scale information regarding the relative importance of attributes. The weighting process combines subjective approach and objective methods to arrive at weight values since several formal procedures have been developed in management science that facilitate this process and make it more objective, such as pairwise comparison and Rank Order Centroid methods [16], [10]. Each weight is often required to be within <0, 1> range and that the sum of all weights equals 1, but this requirement depends on the decision making method.

The values in the decision matrix are then transformed using one of decision support methods, which try to determine the best alternative or a collection of desirable alternatives from a set of evaluated ones. They simplify comparisons among the competing alternatives by providing a single composite measure for each alternative when all attributes must be considered simultaneously. This single measure informs the decision maker which alternatives are desirable, as compared to the others. Among the most popular approaches are the SAR, SAW, TOPSIS, AHP, DEA and PROMETHEE methods [7].

The SAR method (Simple Additive Ranking) is based on the ranking of the alternatives of each criterion, the subsequent aggregation of the weighted ranks and, finally, on the normalization of the obtained values. Simple Additive Weighting (SAW) method calculates the weighted sum of normalized attribute values. TOPSIS, the Technique for Order Preference by Similarity to Ideal Solution, is based on choosing the best alternative having the shortest distance to the ideal solution and the farthest distance from the negative-ideal solution [9]. Analytic Hierarchy Process (AHP) divides complex decision problems into a hierarchical system of decision elements, with weights obtained from the eigenvector of the pairwise comparison matrix. The alternatives are rated using hierarchical additive weighing method [15]. The family of approaches based on Data Envelopment Analysis (DEA) use non-parametric, linear programming based techniques for measuring the relative efficiency of homogeneous units that consume incommensurable multiple inputs and produce multiple outputs [3] [12]. PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation) introduces 6 types of attribute preference functions and a set of algorithms that try to eliminate the fact that good and poor criteria values can fully compensate each other [1]. There are more methods as well as their combinations modifications and extensions, mainly by introducing fuzzy numbers [16] or special criteria to address uncertainty [17].

3. THE GENERALIZED PARAMETER METHOD

The Generalized Parameter Method (GPM) has been originally proposed as a tool for assessment of complex objects or processes, such as logistics [5] [6] or quality of

life [4]. The procedure allows to synthetically evaluate the whole object as well as its components or sub-processes. It can also be used to examine and compare the changes in structure or performance of phenomena in time or with others. In terms of the MCDM problem, there are several alternatives and attributes – criteria of analysis. What is unique to this method is that the attributes have to be organized into logical groups which represent various areas of interest (features, activities, common utility functions etc.).

Once all alternatives are collected, the procedure can be divided into four steps. In the first, initial step, the attributes of the examined object are determined, along with their types and weights, which build up the criteria of the MCDM. The attributes are organized into groups (or compound attributes are decomposed down into sub-attributes). For each attribute its domain or value scale is determined and its type. The type of an attribute reflects the direction or target of desired values. An attribute can be assigned into one of three types: stimulant, destimulant or nominant. A stimulant-type attribute is a higher-the-better one, whereas a destimulant is the opposite, lower-the-better one. A nominant-type attribute has an optimal value (or a range) associated with the highest utility function, and lower or higher values are less desired. For each attribute, its weight is determined as the measure of relative importance compared to the other attributes. The weights can be obtained using any method mentioned above. The groups of attributes must have their own separate weights assigned as well.

The second step involves preparing the decision matrix. The attribute values for all alternatives are gathered or assessed and organized into a matrix. Finally all the numbers are normalized using unitarization, which guarantees that all values have the desired direction towards 1. The normalized value depends on the type of the attribute – stimulant or destimulant, where formulae (1) and (2) are used respectively:

$$y_{ij} = \frac{x_{ij} - x_{i,\min}}{x_{i,\max} - x_{i,\min}}, \qquad (1)$$

$$y_{ij} = 1 - \frac{x_{ij} - x_{i,\min}}{x_{i,\max} - x_{i,\min}}, \qquad (2)$$

where:

y_{ij} – normalized value of ith attribute ($i = 1, ..., n$) and jth alternative ($j = 1, 2, ..., m$),

x_{ij} – raw value of ith attribute and jth alternative,

$x_{i,max}$ – maximum value of ith attribute of all alternatives j,

$x_{i,min}$ – minimum value of ith attribute of all alternatives j.

In case of the attributes which have the same value across all alternatives, the attribute is removed from the decision matrix (we can keep it for comparison with future

decisions though, with all values normalized to either 0 or 1). After the normalization, all the attribute values y_{ij} fall into <0, 1> range, where 0 is the least preferred value and 1 is the most desired value, despite the type of the attribute.

In the third step, the generalized parameter of each group of attributes (GPMG) for each alternative is calculated as weighted sum of all normalized values within a group, divided by the sum of the weights used, according to the formula (3).

$$GPMG_{kj} = \frac{\sum_{i=1}^{n} w_i^{(k)} y_{ij}^{(k)}}{\sum_{i=1}^{n} w_i^{(k)}}, \tag{3}$$

where:

$GPMG_{kj}$ – the generalized parameter of j-th alternative for attributes of k-th group,

$w_i^{(k)}$ – the weight of i-th attribute, if the attribute is within group k,

$y_{ij}^{(k)}$ – the normalized value of i-th attribute and j-th alternative, if within group k.

In the last, fourth step, the total generalized parameter (GPMT) for each alternative is calculated as weighted sum of all group parameters (GPMG) computed above, divided by the sum of all the weights (weights of groups are used, not the weights of individual attributes), according to the formula (4).

$$GPMT_j = \frac{\sum_{k=1}^{l} w_k GPMG_{kj}}{\sum_{k=1}^{l} w_k}, \tag{4}$$

where:

$GPMT_j$ – the total generalized parameter for j-th alternative,
$GPMG_{kj}$ – the generalized parameter of j-th alternative for attributes of k-th group,
w_k – the weight of k-th group of attributes ($k = 1, 2, ..., l$).

All the obtained GPMG and GPMT results – the generalized parameters for groups of attributes as well as the final values, fall into <0, 1> range. The result equal to 0 for an alternative means that all normalized attribute values equal 0. Higher value means better score for an alternative, up to 1 which is the ideal alternative with all maximum attribute values.

As in many other MDCM methods, the final results (the total generalized parameter values GPMT) are eventually used to rank order alternatives and select the best one. The proposed method has an advantage in case when several alternatives are similar in qual-

ity (or utility function etc.), i.e. have equal GPMT values (or similar at a very high level, at the top of the ranking). The decision maker can examine the GPMG values of these competing alternatives then, to find out in which attribute groups they differ one from another. There is no need to look at individual attribute values.

4. CASE STUDY

To analyze how the proposed method can be used and what is its advantage, we demonstrate actual case of a big company with long-term agreements with computer hardware vendors. The IT managers are about to order many notebooks and the decision is pending about whether to buy one of the offered ones or to look for another vendor/brand.

We have chosen 11 alternatives to compare between. The detailed specifications and prices of 8 notebooks have been offered by cooperating suppliers (HP, Dell, Lenovo). Characteristics of the remaining 3 models come from a business notebook review website. The alternatives are: HP EliteBook 8460p, Dell Latitude, Samsung Series 7, HP EliteBook 2560p, Sony VAIO, HP ProBook 4530s, HP Folio 13 Series, Dell Inspiron XPS, Lenovo ThinkPad Edge 520, Toshiba Portege Z835, and Lenovo ThinkPad X220, denoted A1 to A11 respectively.

The criteria "C" (the attributes) have been determined and organized into groups "G" by IT specialists and are presented in Table 1. Redundant criteria, or the ones that are met by all alternatives, have already been removed from the analysis. All criteria but Weight and Thickness are stimulants, i.e. higher values are desired. For Weight and Thickness the lower values are better.

Table 1. The criteria organized into groups

Group/ Attrib.	Explanation
1	**2**
G1	**Performance and storage: the computing power and memory capacity.**
C1.1	CPU type: the processor architecture, graded by an IT expert – values 1, 2 or 4 for Intel i3, i5 or i7 respectively (the higher value for the i7 reflects double number of cores). AMD and other brand CPUs are not considered.
C1.2	CPU speed: nominal value in GHz.
C1.3	RAM size: nominal value in GB.
C1.4	Hard drive capacity: nominal value in GB. Notebooks featuring SSD drives were excluded as SSD drives have much smaller capacity and are expensive.
G2	**Display: the graphics adapter (GPU) performance and screen characteristics.**
C2.1	Graphics integrated: 1 for CPU-integrated or 0 for discrete GPU. Business users are not gamers, so they don't require a discrete top-performance graphics adapter. Most Intel CPUs have a GPU integrated so this solution is preferred.

1	2
C2.2	Screen size: nominal value in diagonal inches of the LCD display. A 12" to 16" display is required.
C2.3	Screen resolution: the number of rows and columns of pixels on the screen. The value is denoted as the number of pixels horizontally only, since vertical pixels depend on the former value in all analyzed models (1366x768, 1600x900).
C2.4	Non-glare display: 1 if antiglare, 0 if glossy LCD coating. The glossy LCDs are better for gaming and watching movies, whereas antiglare ensures better readability in all lighting conditions, which is required for mobile business users.
G3	**Connectivity: how the notebook will connect to the Internet and other devices.** All considered notebooks have both an Ethernet port for regular wired access and a wireless interface for Wi-Fi access.
C3.1	GSM modem: 1 if a SIM-card slot is built-in (or a notebook is bundled with an adapter, like ExpressCard), 0 otherwise.
C3.2	Bluetooth: a way to wirelessly connect to external devices that also have the Bluetooth feature, like mobile phones. 1 if available, 0 if not.
C3.3	USB3 ports: number of the latest-standard USB-3 sockets available.
C3.4	Digital video out: an HDMI or similar digital port to obtain good quality video signal and to be able to connect a digital-only projector without an adapter.
G4	**Portability: how the notebook proves useful for a mobile user – its physical characteristics and battery life.**
C4.1	Weight: in kilograms, with a standard battery.
C4.2	Thickness: in millimeters, at the thickest side. Not the overall size is measured, (with width and height), as these dimensions depend on the screen size (C2.2).
C4.3	Battery life: a regular battery life in hours, as specified by the producer.
C4.4	Case design: durability of the case and socket layout. As determined by experts or web-based reviews): 1 if durable and ergonomic, 0 if not.
G5	**Extras: features considered useful but not necessary.**
C5.1	SD Card reader: useful for some employees who take pictures of client facilities, to transfer them to the hard drive. 1 if present, 0 if not.
C5.2	Fingerprint sensor: for quick user login. 1 if present, 0 if not.
C5.3	Optical drive: 1 if present, 0 if not.
C5.4	Security software: bundled encryption systems etc. 1 if present, 0 if not.
G6	**Service and support: usually vendor-specific assurance systems which help cope with problems and allow to carry on with continuous business operations.**
C6.1	Years in warranty: number of years covered in standard or offered.
C6.2	Premium warranty: door-to-door broken/fixed notebook pickup and delivery, on-site repair, replacement equipment etc. 1 if provided, 0 otherwise.
C6.3	Support channels: ways to look for help and advice in case of issues – like support hotline, online chat, extensive FAQs etc. 1 if outstanding, 0 if standard.

The price for a new notebook is not considered at this stage. Obviously, it should always be considered as a criterion before purchasing decision, but not necessarily as a criterion in a decision-making model. In case of a corporate purchase decision, where many identical items are ordered, the price is negotiated, determined from a contract proposal prepared as a response to a query, or obtained from

an online store if the price quotation is not available. The IT department budget for notebooks is confronted then with the unit price and number of items required. If the budget does not allow to order intended number of notebooks, a cheaper alternative may be analyzed or the budget extended. Presented analysis follows that rule and focuses on the performance, physical and support criteria only. The final choice will be made by the IT staff after judging prices and features of the top-rated alternatives.

Table 2 presents the decision matrix along with the weights of groups of attributes (Wg) and the weights of the individual attributes/criteria (Wc). All the weights have been assigned by the IT staff specialists according to the company requirements. Stimulant and destimulant attributes are denoted "S" and "D" respectively.

Table 2. The decision matrix

Grp	Wg	Attr	Type	Wc	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
G1	3	C1.1	S	3	4	2	2	2	1	1	2	2	1	1	2
		C1.2	S	1	2,0	2,6	2,4	2,5	2,3	2,2	1,6	2,66	2,3	2,2	2,5
		C1.3	S	1	4	8	6	4	4	4	4	4	4	4	6
		C1.4	S	1	320	320	750	250	320	500	128	500	320	128	320
G2	2	C2.1	S	1	1	1	0	1	0	1	1	0	1	1	1
		C2.2	S	2	14	14	14	12,5	15,5	15,6	13,3	15,6	15,6	13,3	12,5
		C2.3	S	1	1366	1366	1600	1366	1366	1366	1366	1366	1366	1366	1366
		C2.4	S	2	1	1	0	1	0	1	1	0	1	1	1
G3	1	C3.1	S	1	1	1	0	0	0	0	0	1	0	0	0
		C3.2	S	1	1	1	1	1	1	1	1	1	1	0	1
		C3.3	S	2	2	0	2	0	0	1	0	2	0	1	1
		C3.4	S	2	0	1	1	0	1	1	1	1	1	1	1
G4	3	C4.1	D	3	2,07	2,07	1,95	1,67	2,71	2,37	1,50	2,71	2,50	1,12	1,54
		C4.2	D	2	31,8	32,4	22,3	27,4	34,0	28,7	17,5	38,2	32,3	15,0	35,0
		C4.3	S	3	13	8	9	8	6	6	9	4	6	8	9
		C4.4	S	1	1	1	1	0	1	1	1	0	0	1	1
G5	1	C5.1	S	1	1	1	1	0	1	1	0	1	1	1	1
		C5.2	S	2	1	1	0	1	0	1	0	0	1	1	1
		C5.3	S	1	1	1	1	1	1	1	0	1	1	0	0
		C5.4	S	1	1	1	0	1	1	1	0	1	1	0	1
G6	2	C6.1	S	2	3	3	1	3	1	1	1	1	1	1	3
		C6.2	S	2	0	1	0	0	0	0	0	1	0	0	1
		C6.3	S	1	1	1	0	1	0	1	1	1	1	1	1

After normalization, the generalized parameters for groups of attributes have been calculated (GPMGn) and the final result GPMT, presented in table 3.

Table 3. The GPMG results for groups and the total GPMT

Result	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
GPMG1	0,61	0,54	0,54	0,34	0,16	0,19	0,17	0,43	0,16	0,09	0,44
GPMG2	0,66	0,66	0,33	0,50	0,32	0,83	0,59	0,33	0,83	0,59	0,50
GPMG3	0,67	0,67	0,83	0,17	0,50	0,67	0,50	1,00	0,50	0,50	0,67
GPMG4	0,64	0,45	0,61	0,47	0,23	0,35	0,75	0,00	0,17	0,81	0,57
GPMG5	1,00	1,00	0,40	0,80	0,60	1,00	0,00	0,60	1,00	0,60	0,80
GPMG6	0,60	1,00	0,00	0,60	0,00	0,20	0,20	0,60	0,20	0,20	1,00
GPMT	**0,66**	**0,66**	**0,45**	**0,47**	**0,24**	**0,45**	**0,40**	**0,40**	**0,38**	**0,45**	**0,63**

We can rank-order the alternatives according to the GPMT from the highest to the lowest value. Two alternatives have the same top GPMT value (A1 and A2). The third notebook A11 has only slightly lower result. The decision maker can now look at the GPMG values of the three competing alternatives to examine the differences among them.

5. CONCLUSIONS

Poor notebook choices in organizations lead to reduced productivity of mobile employees, shorter equipment life cycles and higher costs. The decision maker has to understand the company and user requirements, to make the right trade-offs regarding performance, size, weight, battery life etc. and finally has to prepare a list of attributes, or assessment criteria, along with their desired values or targets. Due to the complexity of notebooks and variety of models on the market, the decision situation is often overwhelming. Multi-criteria decision support methods can be helpful in such cases – when many alternatives have to be considered across many attributes. The method we propose in this paper is especially suitable for notebook purchase decision problems, as notebook attributes can easily be organized into logical groups. The decision maker can rank order and compare the final compound utility values as well as the ones calculated for the groups of criteria. Eventually, an objective and well justified decision can be made.

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FPGA-BASED SIMULATION OF A CIPHER UNIT BUILT USING REVERSIBLE LOGIC

In this paper a novel concept of implementation of an encryption and decryption unit is presented. It is based on using reversible logic. The idea of reversible logic was create for quantum computers. Was developed a reversible gates and methods of reversible function synthesis. In this work a design of a cipher unit built with reversible gates is described. The reversible gates was simulated using FPGA device. Implementation of this project was presented in VHDL and embedded in FPGA device. Synthesis and simulation of project was done using Altera Quartus system and Aldec Acive-HDL system. Both systems are effective and friendly tools for rapid design and simulations. As a result of this work simulation of the cipher has been performed. The cipher was design in various mode. One was simple cipher using only reversible function and then the complex cipher with two additional modules.

1. INTRODUCTION

Research on reversible logic circuits is motivated by advances in quantum computing, nanotechnology and low-power design. Many developers works with designing of classical digital devices like registers, adders, processors etc. using reversible circuits. Recently they have also tried to build more complex devices like for example an encryption devices [1, 5, 7, 8], however, only for saving energy. The other point of view, presented in this paper, is to use some features of reversible function. One of them is a big number of functions. For n variables exist $2^n!$ different function. There are 24 reversible functions for 2 variables, 40320 functions for 3 variables and more than 20×10^{12} for 4 variables.

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A reversible function is a vector n Boolean functions, each of them being a function of n variables and a one-to-one correspondence between its inputs and outputs. The truth table of a reversible function has 2^n rows. To each n-bit input vector corresponds a unique n-bit output vector. Each of the output functions is balanced, i.e. the number of rows with output "1" is equal to the number of rows with output "0". Reversible gates are used to implement reversible functions. Reversible circuits are cascades of reversible gates.

Reversible logic synthesis has been extensively studied and many types of reversible gates have been proposed. The attention has been devoted mostly to the synthesis of circuits built from the NCT library composed of NOT, CNOT and Toffoli gates [2]. In this paper we use this set of reversible gates. Its subset is shown in Fig. 1.
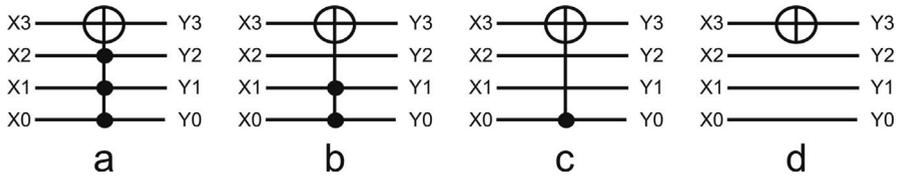
Fig. 1. Examples of reversible gates a) T gate, b) T-AND gate, c) C gate, d) N gate

In Figure 1 eight reversible gates composed with XOR gate at line X3 are presented (1 gate of type T from Fig. 1a, 3 gates of type T-AND from Fig. 1b, 3 gates of type C from Fig. 1c, and 1 gate of type N from Fig. 1d). The T-AND gate shown in Fig. 1b is also denoted as T3-10. Similarly, there exist 8 gates with XOR gate at line X2, 8 gates with XOR gate at line X1 and 8 gates with XOR gate at line X0. Thus, in total, there are 32 reversible gates with 4 inputs/outputs. Implementation of any reversible function can be done using a cascade circuit presented in a Fig. 2.
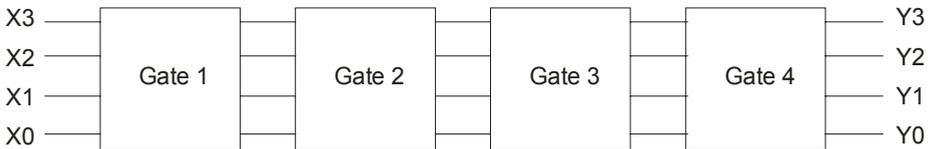
Fig. 2. Cascade circuit built from reversible gates

The maximal length of an optimal (minimal) circuit is 8 for 3 variables function and 15 for 4 variables function. Designing optimal circuits for reversible functions with more than 3 variables is a very hard problem.

2. IMPLEMENTATION OF REVERSIBLE GATES IN FPGA

We implement the above described set of 4-input/output reversible gates using an FPGA structure. We have simulated these gates as shown in Fig. 3. Behavioral description of the gates have been used. In this figure the small ring denotes a configuration fuse. The fuse could be opened (no connection) or closed (i.e., with a connection between left and right side). By proper programming these fuses one can obtain a particular gate.

As you can see in Fig. 3 each line X_i can be connected to output Y_i directly or via the corresponding XOR gate. Another input of XOR gate is connected to the output of the AND gate or with "1". If it is connected with the AND gate then T_i or C_i gates are realized, and if it is connected with "1" then N_i gate is realized. Such configuration enables for implementation of all kind of gates.
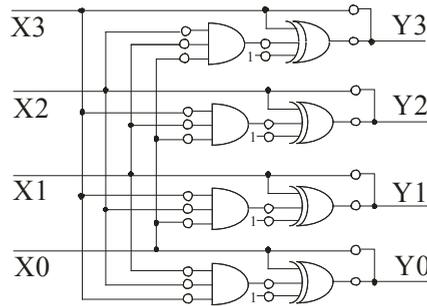
Fig. 3. Circuit capable of implementing any 4-input/output reversible gate

An example of a configuration of the circuit from Fig. 3 is shown in Fig. 4. Closed fuses are black and opened fuses are white.
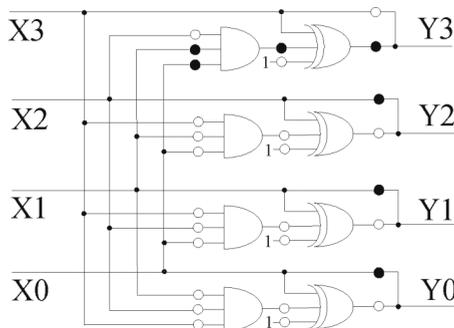
Fig. 4. Configuration of a circuit for implementation gate T3-10

An implementation of Toffoli gate T3-10 is presented in the Fig. 4. The XOR gate is realized on the line 3. Inputs X0 and X1 are connected to inputs of the AND gate. The circuit implements the function $Y3 = X3 \oplus X1 \cdot X0$.

3. IDEA OF ENCRYPTION

Every circuit implementing a reversible function can be treated as a cipher. The sequence of n-input vectors is the plaintext and the sequence of n-output vectors are is the ciphertext. If $n = 8$ than any input byte is converted into another byte. In this case the reversible function is 8-variable. However, the problem of finding cascade circuits realizing 8-variable reversible function is very difficult. Therefore, we decomposed an 8-input circuit into two 4-bit circuits. The realization problem is easier for 4-variable reversible function [6]. Maximum number of gates in an optimal 4-input cascade is 15 [3]. We consider a 16-gate cascade. Depending on a given reversible function different cascade circuits will be obtained. These circuits corresponds to a cryptographic key. Because we assume 16-gate cascade and there exist 32 various gates we use 80-bit key for a 4-input cascade (16×5). Hence, for two cascades a cryptographic key will consist of 160 bits.

To implement 4-input cascade we need to find proper solution of 4-variable function as the encryption key. There are more than 20×10^{12} 4-variable functions and most of them have large number of optimal solutions. The problem of choosing the best solution is quite hard so we are not discussing it here.

In Fig. 5 a concept of cipher unit built with two 4-input cascades is presented. The cipher from Fig. 5 uses a substitution method [4].
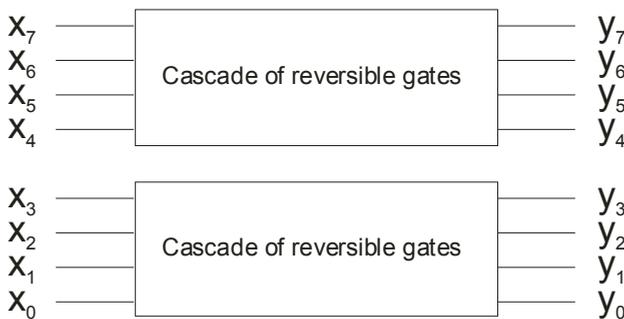
Fig. 5. Cipher encoder with two reversible cascades

To include more complex encryption we enhanced coder with two mechanisms. One is a cross-bar matrix for coding inputs (see Fig. 6) and for decoding outputs. Be-

cause the cross-bar matrix has 64 connection points (the number of available connections is 8! = 40320) so the length of the key has to be increased to 176 bits.
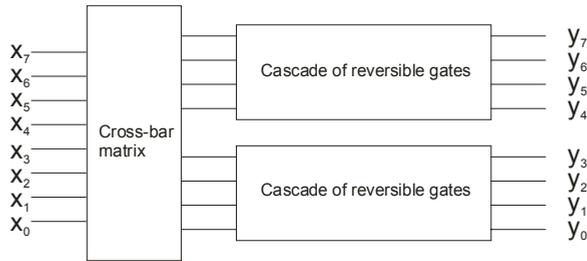
Fig. 6. Coder with input cross-bar matrix

The second mechanism is a dynamic key transformer. Depending on the number of transformation methods applied the length of cryptographic key may increase. For example, if we apply 256 transformation methods the length of the key grows up by 8 bits to 184 bits.
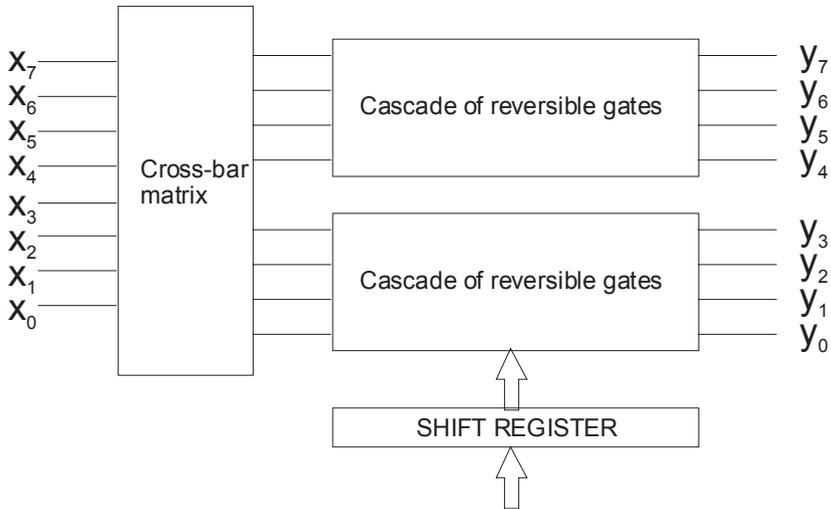
Fig. 7. Structure of a cipher block

We have designed the key register as a shift register. We can shift the contents of the 160-bits key register by a different number of positions. This number can be choose from 1 to 160. It correspond to 8 additional bits in key word. In real we use only 6 bits so the length of key is 182 bits.

4. CIPHER IMPLEMENTATION

We have designed all 4-input reversible gates as the function called `bramka`. Description of this function is shown in Fig. 8.

```
-- funkcja obliczająca wynik działania wskazanej bramki ----------------
----------
type typ_bit_arr is array (3 downto 0) of std_logic;
function bramka (X : in  std_logic_vector;
K : in  std_logic_vector) return std_logic_vector is
variable Y : typ_bit_arr;
begin
if    K=x"D0" then Y(2):=X(2); Y(1):=X(1); Y(0):=X(0); Y(3):=not X(3);
elsif K=x"D1" then Y(2):=X(2); Y(1):=X(1); Y(0):=X(0); Y(3):=X(3) xor
X(0);
elsif K=x"D2" then Y(2):=X(2); Y(1):=X(1); Y(0):=X(0); Y(3):=X(3) xor
X(1);
elsif K=x"D3" then Y(2):=X(2); Y(1):=X(1); Y(0):=X(0); Y(3):=X(3) xor
(X(1) and X(0));
elsif K=x"D4" then Y(2):=X(2); Y(1):=X(1); Y(0):=X(0); Y(3):=X(3) xor
X(2);
elsif K=x"D5" then Y(2):=X(2); Y(1):=X(1); Y(0):=X(0); Y(3):=X(3) xor
(X(2) and X(0));
elsif K=x"D6" then Y(2):=X(2); Y(1):=X(1); Y(0):=X(0); Y(3):=X(3) xor
(X(2) and X(1));
elsif K=x"D7" then Y(2):=X(2); Y(1):=X(1); Y(0):=X(0); Y(3):=X(3) xor
(X(2) and X(1) and X(0));
elsif K=x"C0" then Y(3):=X(3); Y(1):=X(1); Y(0):=X(0); Y(2):=not X(2);
elsif K=x"C1" then Y(3):=X(3); Y(1):=X(1); Y(0):=X(0); Y(2):=X(2) xor
X(0);
--------------------------------------------------------
elsif K=x"B4" then Y(3):=X(3); Y(2):=X(2); Y(0):=X(0); Y(1):=X(1) xor
X(2);
elsif K=x"B5" then Y(3):=X(2); Y(2):=X(2); Y(0):=X(0); Y(1):=X(1) xor
(X(2) and X(0));
--------------------------------------------------------
elsif K=x"A2" then Y(3):=X(3); Y(2):=X(2); Y(1):=X(1); Y(0):=X(0) xor
X(1);
elsif K=x"A4" then Y(3):=X(3); Y(2):=X(2); Y(1):=X(1); Y(0):=X(0) xor
X(2);
elsif K=x"A6" then Y(3):=X(3); Y(2):=X(2); Y(1):=X(1); Y(0):=X(0) xor
(X(2) and X(1));
--------------------------------------------------------
end if;
return (Y(3)&Y(2)&Y(1)&Y(0));
end function bramka;
```

Fig. 8. Description of a reversible gate

Function `bramka` is used to design cipher and decipher circuits. The cipher circuit contains two modules BSA and BSB (cascades of reversible gates) and the decipher circuit contain two modules BDA and BDB. Description of these modules is presented in Fig. 9.

```
--======= SZYFRATOR ======-----------------------------------------------
szyfrowanie: for I in 0 to 15 generate
BSAi: WS_AA(i+1)<=bramka(WS_AA(i),RKL_SA(i));
BSBi: WS_BB(i+1)<=bramka(WS_BB(i),RKL_SB(i));
end generate szyfrowanie;


--======= DESZYFRATOR ======--------------------------------------------
WD_AA(16)<=DWED(7 downto 4);
WD_BB(16)<=DWED(3 downto 0);
deszyfrowanie: for I in 15 downto 0 generate
BDAi: WD_AA(i)<=bramka(WD_AA(i+1),RKL_SA(i));
BDBi: WD_BB(i)<=bramka(WD_BB(i+1),RKL_SB(i));
end generate deszyfrowanie;
```

Fig. 9. Description of encryption and decryption blocks

The byte sequence of plaintext is coming at the inputs of the encryption modules, particularly at the inputs of cross-bar block. The output signals of cross-bar block WS_AA(0) and WS_BB(0) are the inputs signals of BSA and BSB modules. The output signals of reversible cascades are the bytes of the ciphertext WS_AA(16) and WS_BB(16).

The byte sequence of ciphertext during decryption process is denoted as the signals DWED and is a input of decryption unit. The output signals of this unit are WD_AA(0) and WD_BB(0). These signals are applied to inputs of the cross-bar block. The outputs of the cross-bar block are the bytes of plaintext.

We used a pair of keys `RKL_SA` and `RKL_SB` for both cascades of encryption and decryption modules, respectively.

5. CIPHER BLOCK SIMULATION

The subsequent bytes from 0 to 255 are used as input test signals TB_DWES for encryption unit. The output signals TB_DWYS of the encryption unit are the bytes of ciphertext. This ciphertext is applied to inputs TB_DWED of the decryption block and the outputs of this block are the signals TB_DWYD.

Fig. 10. Simulation of encryption and decryption processes

As we can see from Fig. 10 the output signals from the decryption unit are the same as the input plaintext of the cipher unit. This circuit is cascade of reversible gates. It works as cipher with constant key. This key is stored in registers *RKL_SA i RKL_SB*.

Fig. 11. Simulation of encryption and decryption processes

In Figure 11 is result of simulation the more complex cipher unit. This is the cipher with still constant cipher key but additionally is implemented commutation of inputs and outputs. In this example cross-bar module swap inputs 0 with 7 and 6 with 2. Inputs 1, 3, 4 and 5 are on the same place. The influence of commutation we can see when we compare outputs waves TB_DWYS from Fig. 10 and Fig. 11.
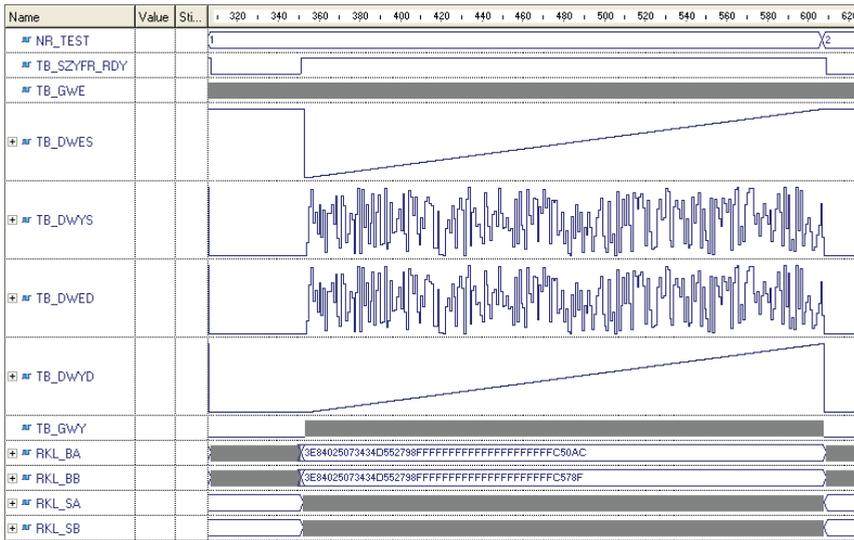
Fig. 12. Simulation of encryption and decryption processes

On Fig. 12 is result of simulation the cipher unit built as reversible gates cascade with cross-bar modules on input of encryption unit and on output of decryption unit and additionally is implemented shifter of key register. After coding process of every subsequent byte the key register is shifting with programmed number of bits. The output wave on the TB_DWYS is more random then previously simulations.

6. CONCLUSIONS

In this paper we propose a novel implementation of encryption and decryption processes. It uses a reversible logic and reversible circuits for these purposes. Experimental results show that it is possible to design such cipher blocks with high complexity. This depend on reversible function, programing of inputs and outputs commutation and mode of key shifter. Further work will be devoted to designing a distribution key process. Most important issues are a synthesis method of reversible functions and the problem of determining bad keys.

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PART 2

KNOWLEDGE MANAGEMENT
FOR NON-PROFIT ORGANIZATIONS

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DETERMINANTS OF UNIVERSITY APPLICANT SATISFACTION IN THE LIGHT OF STUDIES

Because of the increasing role of competition on the educational services market many universities have begun to study the needs of future students and adjust their offer and study conditions to the latter's expectations. Since in the era of intense competition between universities wins the one which is able to meet the needs of its customers it is vital to know the factors guiding university applicants in their choice of a university. This paper presents a study aimed at identifying the factors influencing university choice by applicants.

1. CUSTOMER ORIENTATION
– NECESSITY IN UNIVERSITY MANAGEMENT

The twentieth century witnessed several changes in the activities of Polish universities. Beside the state universities, private universities, whose teaching offer is becoming increasingly attractive, appeared on the educational market. As a result, applicants can choose from a wide range of universities. A number of universities (especially the private ones) began to examine the needs of university applicants and to adapt their courses accordingly.

Considering that nowadays the winner is the university which is able to meet the needs of the largest possible number of customers it is vital to take the needs of university applicants into account. Hence some universities which perceive the necessity to consider applicants as prospective customers have begun to conduct satisfaction surveys. Many studies on factors contributing to student satisfaction, for instance car-

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ried out by Aldrige S. and J. Rowely[1], and R. Ryńca, and D. Kuchta[2], have been published. This paper presents a study aimed at identifying the factors influencing the choice of university by applicants.

2. RESEARCH METHODS

2.1. QUESTIONNAIRE STRUCTURE AND RESEARCH SAMPLE

The questionnaire, on a sheet of paper, was delivered to 450 applicants to the Wrocław universities. Its aim was to find the main reasons (factors) for the choice of a particular university. The questionnaire consisted of 63 questions, each with a closed list of proposed answers. The applicants were to rate, on a scale of 0 to 6 (where 0 means negligible and 6 – very important) the importance of the individual factors determining the choice of university.

In the questionnaire the factors were grouped under the following headings:
1. University standing
   - the prestige of the university;
   - the reputation of the university;
   - the fact that the university is chosen by the most talented applicants, including school-contest prize winners;
   - employers' good opinion of the university and their preferences;
   - the academic community's good opinion of the university;
   - the family's good opinion of the university;
   - friends/colleagues' good opinion of the university;
   - the high position of the university in university rankings;
   - the future students' high satisfaction with studying at the university;
   - the quality of the graduates' education.
2. University research & teaching strength:
   - the research and teaching potential of the staff,
   - the way of conducting classes,
   - the number of professors in the university,
   - the number of highly qualified specialists,
   - the number of employees (practitioners).
3. University promotion and enrolment process:
   - the effective form of university promotion, such as advertising;

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[1] Aldridge, S. and Rowley, J., *Measuring customer satisfaction in higher education*, Quality Assurance in Education, Vol. 6 No. 4, 1998, pp. 198, 199.

[2] Ryńca R., Kuchta D., *Student satisfaction factors* (in Polish), Scientific Papers of the University of Economics in Wrocław, No. 123, 2010.

- the possibility of enrolling on-line;
- the date of the entrance exams;
- no entrance exams;
- the enrolment fee;
- the type of the entrance exams;
- the form and time of the entrance exams.
4. Conditions of study:
    - the high level of teaching;
    - easy access to the faculty, e.g. office hours;
    - the good conditions for foreign languages teaching and the effectiveness of the latter;
    - the wide range of non-compulsory programmes;
    - the individual approach to the student;
    - the stress-free and unproblematic gaining of a university diploma, the fact that optimum conditions for studying have been created;
    - the extracurricular activities offer reflected in the student life atmosphere;
    - the friendly atmosphere for studying;
    - the polite treatment by the faculty and the administrative staff;
    - the training courses offer;
    - the fact that academic seminars and lectures given by well-known figures from the world of science, politics and business are held at the university;
    - the possibility of getting traineeships and placements;
    - the opportunity to acquire practical skills;
    - the possibility of getting a job while studying;
    - the opportunity to participate in activities consistent with one's interests;
    - the opportunity to participate in university associations and scientific circles;
    - the opportunity to acquire academic and research skills;
    - the possibility of continuing studies at the master and doctoral levels;
    - the contacts with other universities;
    - the university infrastructure;
    - the tuition fees;
    - the scholarship system;
    - the organization of study, e.g. no gaps between classes;
5. Topographical considerations:
    - the attractive geographical location of the university,
    - the closeness to the family home,
    - the attractiveness of the university city,
    - the cost of living in the area,
    - the campus is located in one place.
6. Internationalization of studies:
    - curricula taught in foreign languages;

- the large number of students studying in foreign languages;
- the opportunity to go abroad to study at a partner university;
- lectures given in foreign languages;
- the multicultural academic community;
- the large number of teachers from abroad;
- access to summer schools;
- the good programme and personal collaboration with important foreign partners;
- the international exchange of students, facilitated contacts with students abroad.
7. Career prospects:
    - the possibility of acquiring good and solid education,
    - high prospects for a good job after graduation,
    - the high percentage of graduates employed upon graduation,
    - the great opportunity for professional development.

2.2. RESEARCH RESULTS

2.2.1. GRAPHIC ANALYSIS

The results of the questionnaire can be easily analyzed via charts. The most basic of such charts (fig. 1) shows the average rate of each of the identified factors. Since the amount of information contained in this chart is very low, misinterpretations may arise. Therefore the boxplot and PCA charts will be used for the further analysis.
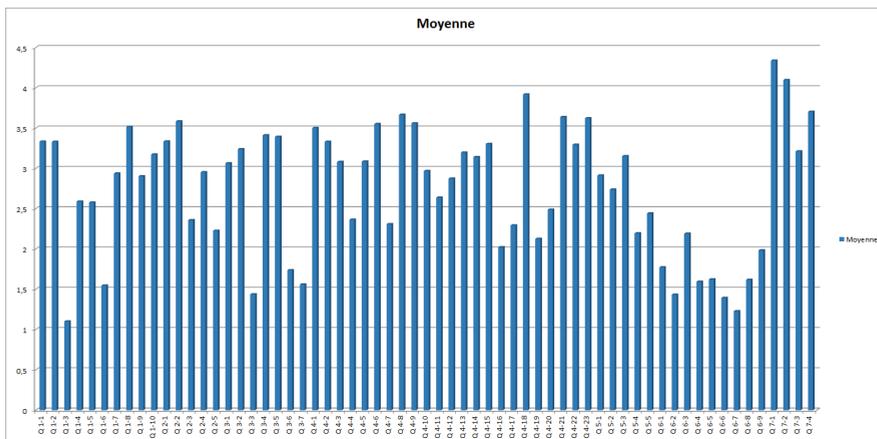
Fig. 1. Average rate of each of factors.
Source: own collaborative research

Figure 1 shows the average answer rate for each of the factors (0 stands for no answer). The chart was made using Microsoft Excel. The symbols representing the factors are explained in the Appendix (tables 1–7). Even though these are raw data, it is already evident that answers within a group of questions may significantly differ from one another. For example, under the "conditions of study", "the opportunity to acquire academic and research skills" (Q 4-17) gets an average rank of 3.9 while "the possibility to continue studies at the master and doctoral levels" (Q 4-18) gets an average rank of 2. This is surprising since the two factors are very similar to each other and most often the opportunity to acquire academic and research skills leads to the possibility of continuing studies at the master and doctoral levels.

2.2.2. BOXPLOT ANALYSIS

The Boxplot is a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), the lower quartile[3] (Q1), the median[4] (Q2), the upper quartile[5] (Q3), and the largest observation (maximum sample).

Figure 2 shows a boxplot of the factors of under "University standing" (the symbols are explained in table 1 in the Appendix). The factors: "the prestige (Q 1-1) and reputation (Q 1-2) of the university" are similarly highly rated. "The high position of the university in university rankings" (Q1-8) and "the quality of the graduates' education" (Q1-10), receiving a median of 4 and a small blue box (which means that many persons feel the same about it), are equally highly rated. Then follow: "employers' good opinion of the university and their preferences" (Q1-4), "the academic community's good opinion of the university" (Q1-5), "friends/colleagues' good opinion of the university" (Q1-7) and "the future students' high satisfaction with studying at the university" (Q1-9), with a median of 3 and a large boxplot (which means that the opinions of the applicants differ much from one another). Finally come: "the fact that the university is chosen by the most talented applicants, including school-contest prize winners" (Q1-3) and "the family's good opinion of the university" (Q1-6), with a median of 0 (which means that these factors are totally irrelevant to the applicants' choice of university). Therefore it seems that university executives should take into consideration first of all the university's image and attach greater importance to the opinions about the university expressed in the national rankings.

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[3] a point which splits the answers into two portions so that 25% of the answers are lower than (or equal to) the median and 75% of them are higher than (or equal to) the upper quartile.

[4] a point which splits the answers into two equal portions so that 50% of the answers are lower than (or equal to) the median and 50% of them are higher than (or equal to) the median.

[5] A point which splits the answers into two portions so that 75% of the answers are lower than (or equal to) the median and 25% of them are higher than (or equal to) the upper quartile.
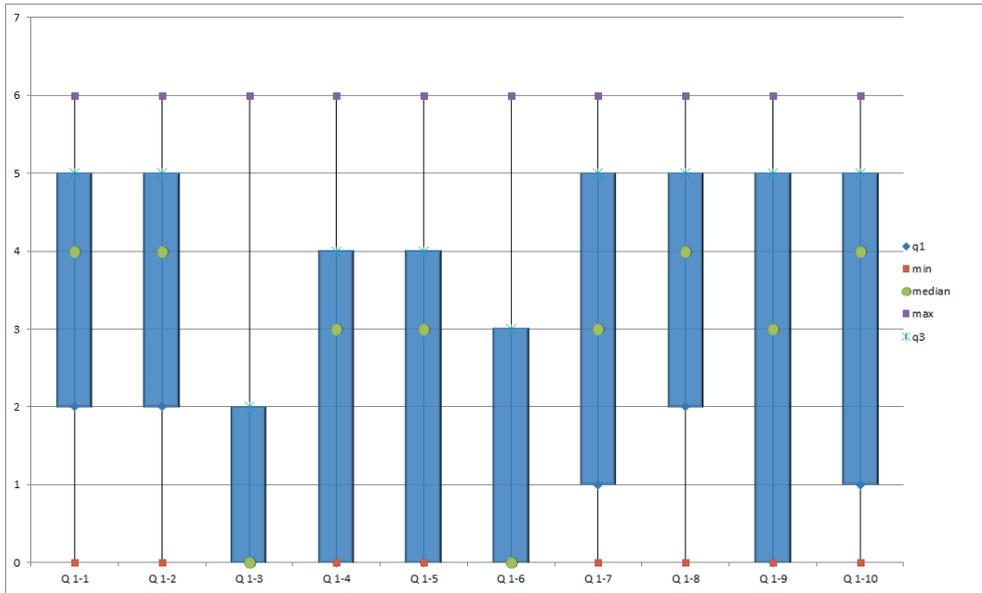
Fig. 2. Boxplot of factors under "University standing".
Source: own collaborative research
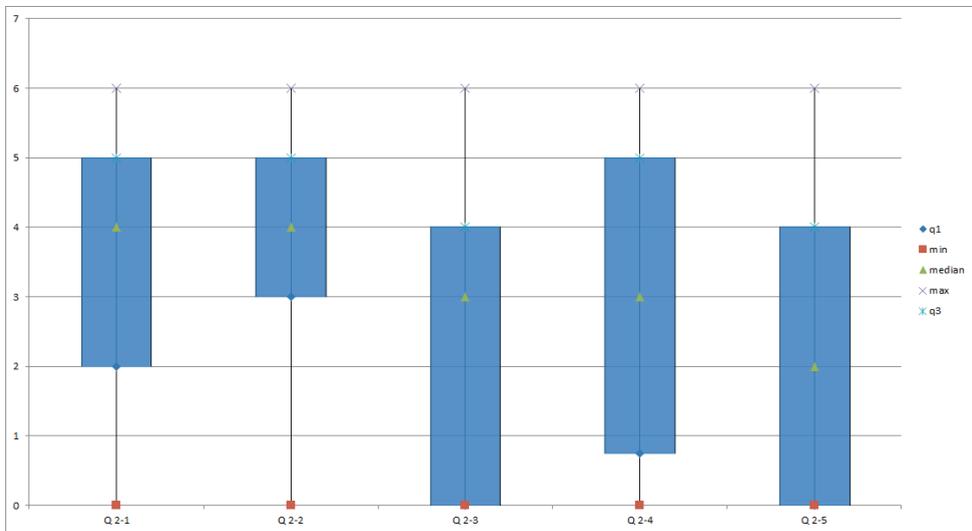
Fig. 3. Boxplot of factors under "University research & teaching strength"
Source: own collaborative research.

Figure 3 shows a boxplot of the factors under "University research & teaching strength" (the symbols are explained in table 2 in the Appendix). It is evident that

quality ("the way of conducting classes" (Q2-2) and "the research and teaching potential of the staff" (Q2-1)) is considered to be more important than quantity ("the number of professors in the university" (Q2-3) and "the number of employees" (Q2-5)). As regards "the number of highly qualified specialists" (Q2-4), the applicants differ in their opinion (as indicated by the large blue box and the median of 3). It seems therefore essential for the management of universities to pay attention to the way classes are conducted by the employees and to take actions to attract highly skilled staff.
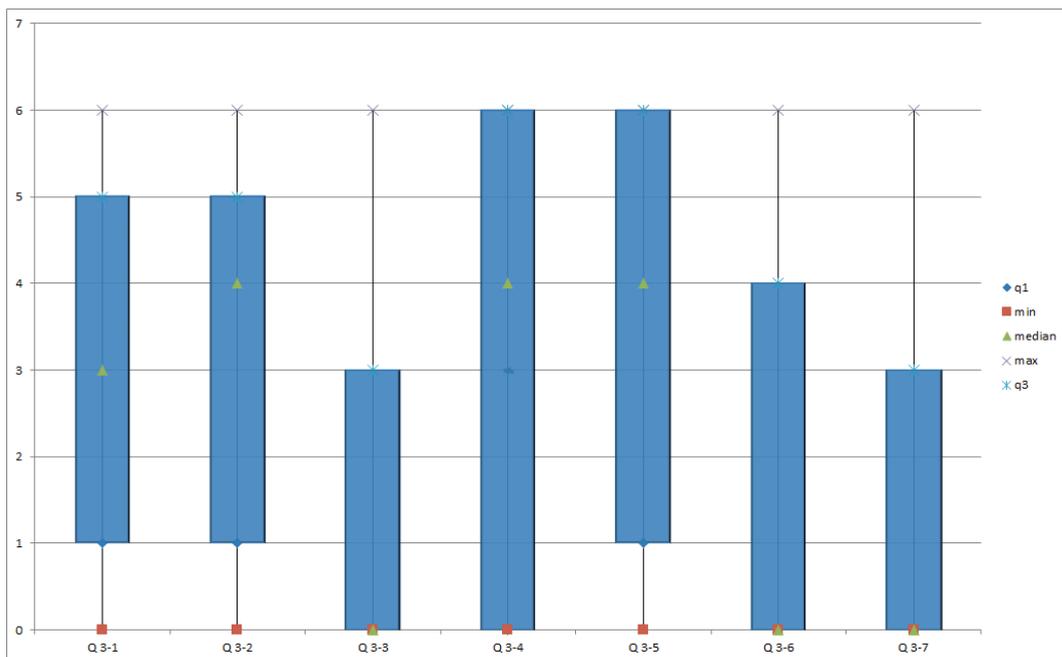
Fig. 4. Boxplot of factors under "University promotion and enrolment process".
Source: own collaborative research

Figure 4 shows a boxplot of the factors under "University promotion and enrolment process" (the symbols are explained in table 3 in the Appendix). It is evident that the applicants look for simplicity ("the possibility of enrolling on-line (Q3-2) and "no enrolment fee" (Q3-5)), but their opinions differ on entrance exams. Obviously "no entrance exams" is viewed by everyone as an easy way to enter university, but entrance exams are also considered to be a good thing if one wants to enter a more selective university. Then follow factors which do not matter to the applicants, i.e. "the date of the entrance exams" (Q3-3), "the type of the entrance exams" (Q3-6) and "the form and time of the entrance exams" (Q3-7)). The exams themselves seem to be an issue, but not their form. Given the intense competition on the educational services market it appears important to ensure a modern form of university enrolment.
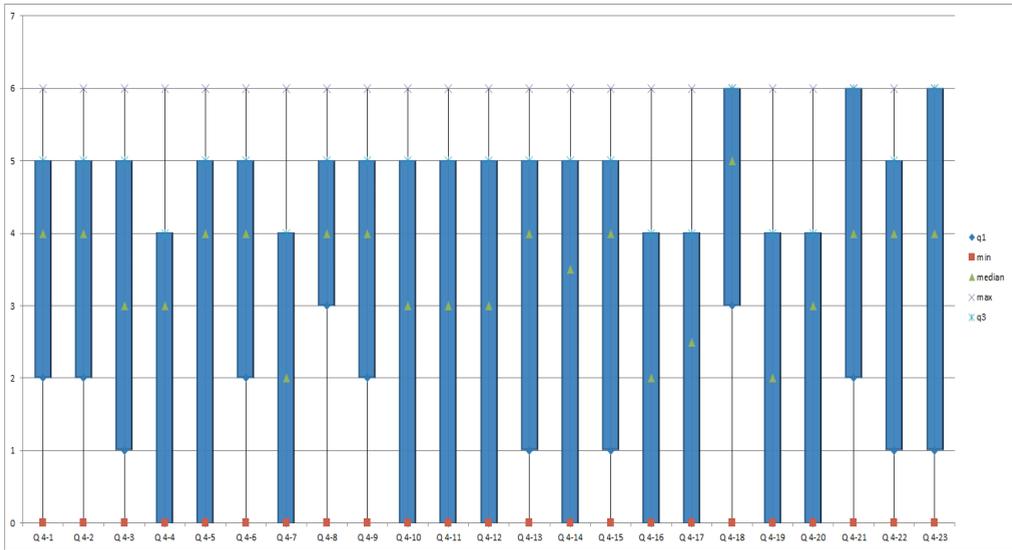
Fig. 5. Boxplot of factors under "Conditions of study".
Source: own collaborative research

Figure 5 shows a boxplot of the factors under "Conditions of study" (the symbols are explained in table 4 in the Appendix)**.** In order to keep the analysis simple, the major points, the points on which opinion varies and the points which are not important at all to the applicants will be examined.

The quality of the diploma seems to be linked to the length of time one spends to obtain it since "the possibility of continuing studies at the master and doctoral levels" (Q4-18) ranks top here. It is followed by practical considerations: "the tuition fees" (Q4-21) and "the organization of study" (Q4-23) are quite an issue for the applicants. Equally highly ranked are "the high level of teaching" (Q4-1), "easy access to the faculty, e.g. office hours" (Q4-2)), "the friendly atmosphere for studying" (Q4-8) and "the polite treatment by the faculty and the administrative staff" (Q4-9)).

The points on which opinion varies widely are: "the training courses offer" (Q4-10), "the fact that academic seminars and lectures given by well-known figures from the world of science, politics and business are held at the university" (Q4-11) and "the possibility of getting traineeships and placements" (Q4-12)). It is clear that all these points are connected with the organization of one's studies, which is a highly individual matter.

The points which applicants consider to be minor are: "the extracurricular activities offer reflected in the student life atmosphere" (Q4-7), "the opportunity to participate in university associations and scientific circles" (Q4-16) and "the contacts with other universities" (Q4-19).

It follows from the above that university management should provide the possibility of continuing studies at the second and third level of education and ensure a high level of teaching. It also seems important to ensure moderate tuition fees and access to the faculty outside of class hours (office hours).
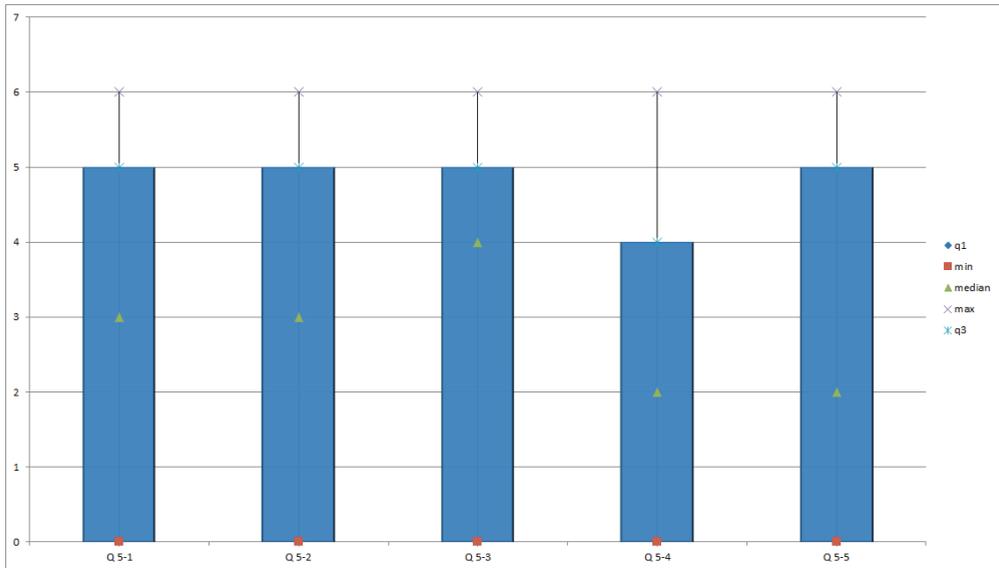
Fig. 6. Boxplot of factors under "Topographical considerations".
Source: own collaborative research

Figure 6 shows a boxplot of the factors under "Topographical considerations" (the symbols are explained in table 5 in the Appendix). This is a peculiar case since the results are quite the same for each of the factors. The only thing that deserves attention is that "the attractiveness of the university city" (Q5-3) ranks higher than "the cost of living in the area (Q5-4). Why such results? The reason is that topographical considerations are highly individual. In comparison with the other factors, they seem minor.

Figure 7 shows a boxplot of the factors under "Internationalization of studies" (the symbols are explained in table 6 in the Appendix). The results are quite surprising. The authors thought that with the success of programmes such as Erasmus and the increasing number of people working abroad in the course of their careers, the internationalization of studies would be a major consideration. But the boxplot shows that the opposite is true. As one can see, all the factors in the category "Internationalization of studies" do not matter to the applicants. It seems that the applicants are not interested in the possibility of studying abroad and gaining new experience in this way.
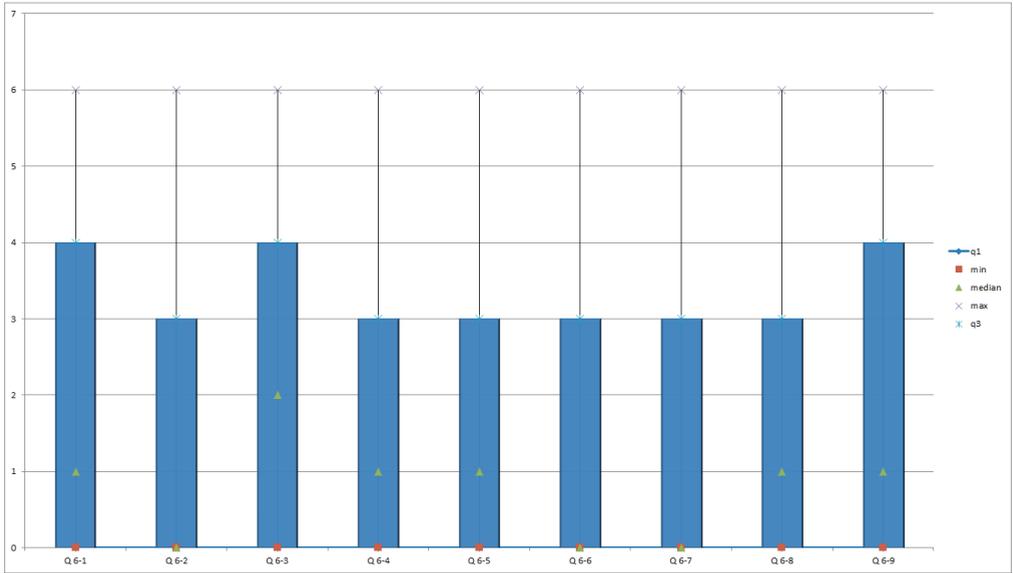
Fig. 7. Boxplot of factors under "Internationalization of studies".
Source: own collaborative research
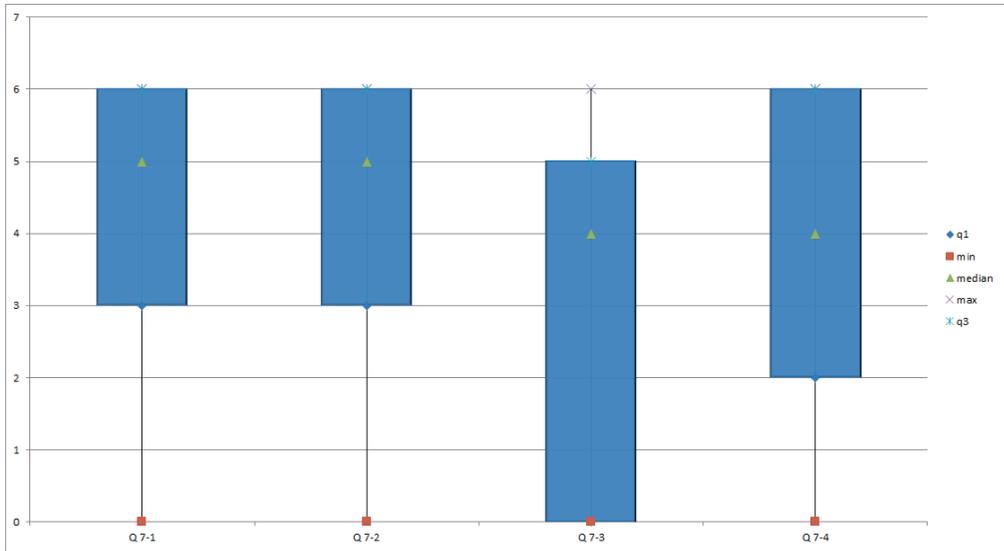
Fig. 8. Boxplot of factors under "Career prospects".
Source: own collaborative research

Figure 8 shows a boxplot of the factors in the category "Career prospects" (the symbols are explained in table 7 in the Appendix). Here, the applicants are very down-

to-earth. Studies are perceived by them as a means to an end. The most highly ranked factors in the whole questionnaire are: "the possibility of acquiring good and solid education" (Q7-1), "high prospects for a good job after graduation" (Q7-2) and "the great opportunity for professional development" (Q7-4). According to the applicants, the only debatable point is "the high percentage of graduates employed upon graduation" (Q7-3). Thus it is clear that applicants will choose the universities which offer high prospects for a good job after graduation.

2.2.3. PRINCIPAL COMPONENT ANALYSIS

The third tool used in this analysis was the Principal Component Analysis (PCA). It is a technique making multivariate data easier to understand. Let us suppose that there is information on n variables for each data item. The variables are unlikely to be independent of one another; whereby a change in one is likely to be accompanied by a change in another. The idea of PCA is to replace the original n variables by m ($<n$) uncorrelated variables, each of which is a linear combination of the original variables, so that the bulk of the variation can be accounted for using just a few explanatory variables. In the diagram overleaf, the two original variables x_1 and x_2 can be replaced by the first principal component, i.e. y_1. This is a very efficient way of representing more than two data in a plane space, seeing if they are correlated and identifying groups of people who follow the same behaviour.

2.2.3.1. INTERPRETATION OF PCA

There are two kinds of charts which can be obtained from PCA: a correlation circle (CC) and a projection of individuals (PoI).

CC is used to see if the different questions are correlated and if the projection of the questions in a plane space is relevant. In CC, red lines represent the projection of the questions (and their answers) in a plane space. If two red lines are perpendicular, this means that they are not correlated. The closer to each other the lines are, the more correlated they are. Furthermore, if the end of a red line is close enough to the circle (red_line_length > 0.90*radius), this means that the projection is relevant and one can use the data.

PoI Is used to find different groups of people following the same behaviour. The X-axis in most cases represents the quantity of a parameter (here, e.g., the X-axis represents the rate of each factor, i.e. from 0 to 6 (unimportant to very important)). The y-axis is more difficult to interpret; it is related to the quality of parameters and differs from case to case.

2.2.3.2. PCA IN PRESENT RESEARCH

In this study, PCA was applied to a group of factors, i.e. the group of factors relating to university standing. PCA (as usual) was carried out in two stages: first

the CC was interpreted and then the different groups of respondents were located in the PoI.
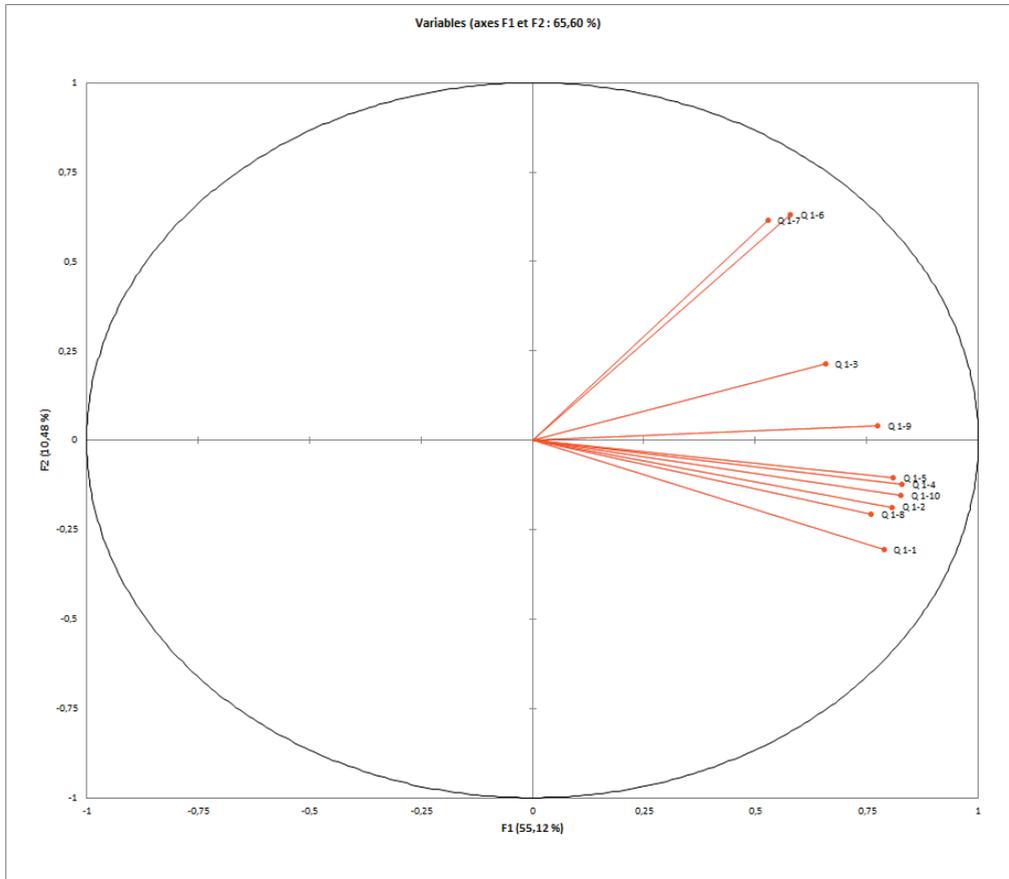
Fig. 9. Correlation circle for group of factors.
Source: own collaborative research

Figure 9 shows a correlation circle for the group of factors. In the CC the X-axis represents the global quality of the university. To the left of the axis there is bad quality and to the right there is good quality. The Y-axis represents the type of university ranking. At the top of the Y-axis there are private opinions (held by the family, colleagues, etc.) of the university while at the bottom there are public opinions (e.g. press rankings). It is surprising, but interesting, to find that that the family's opinion of the university is independent of the latter's prestige and ranking. Since the red line is short, Q1-3, Q1-8 and Q1-9 cannot be used in the analysis.
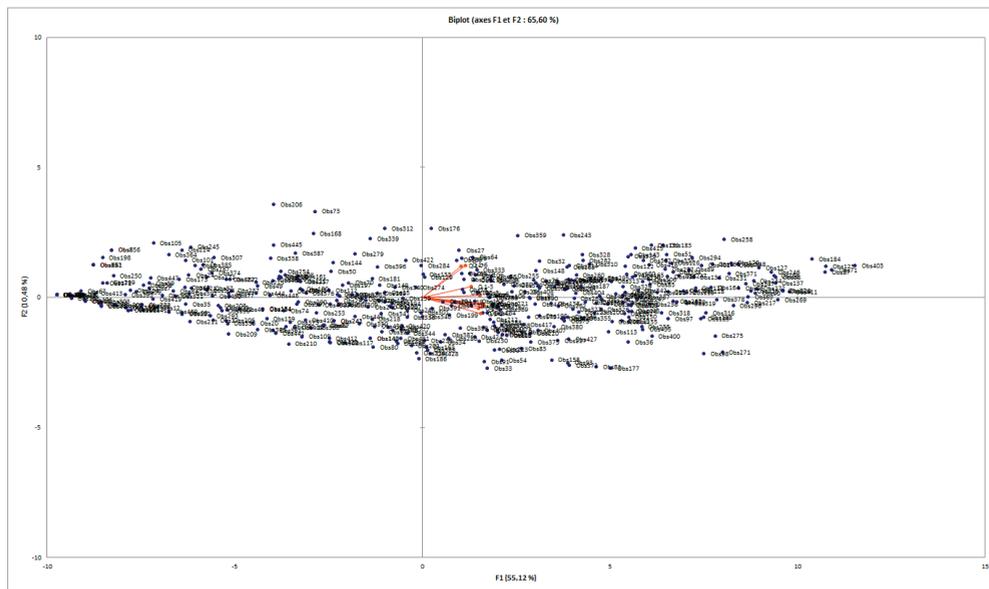
Fig. 10. Projection of individuals within group of questions.
Source: own collaborative research

Figure 10 shows a projection of individuals (PoI) within the group of questions. In the PoI the respondents are represented by black dots in space. The large and dense cloud of dots in fig. 10 means that almost every respondent followed the same behaviour. The cloud is long but not wide, which indicates that the opinions of the applicants on university standing are scattered, but the type of university ranking seems to be highly important to them – it must be public to mean anything.

3. CONCLUSION

The aim of this study was to find what factors determine the choice of university by university applicants. It has been found that the most important factors are: the possibility of continuing studies at the master and doctoral levels, the possibility of acquiring good and solid education and high prospects for a good job after graduations. Also important are: the great opportunity for professional development, the tuition fees, the friendly atmosphere for studying and the way of conducting classes. The following have been found to be unimportant: the fact that the university is chosen by the most talented students, including school-contest prize winners; the family's good opinion of the university; the date of the entrance exams; the type of the entrance exams; the form and time of the entrance exams; the large number of students studying in foreign languages; the large number of teachers from abroad; and access to summer schools.

As previously mentioned, due to the fact that in the era of intense competition between universities wins the one which is able to meet the needs of its customers it is vital to know the factors which guide university applicants in their choice of a university. This paper represents an attempt to identify the factors.

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[2] GRAY B.J., FAM K.S., LLANES V.A., *Branding universities in Asia markets*, Journal of Product and Brand Management, Vol. 12, No. 2, 2003, pp. 108–120.
[3] RYŃCA R., KUCHTA D., *Student satisfaction factors* (in Polish), Scientific Papers of the University of Economics in Wrocław, No. 123, 2010.
[4] VELOUTSOU C., LEWIS J.W., PATON R.A., *University selection: information requirements and importance*, The International Journal of Educational Management, Vol. 18, No. 3, 2004, pp. 160–71.

APPENDIX

Table 1. University standing

Factor Number	Definition
Q 1-1	the prestige of the university
Q 1-2	the reputation of the university
Q 1-3	the fact that the university is chosen by the most talented students, including school-contest prize winners
Q 1-4	employers' good opinion of the university
Q 1-5	the academic community's good opinion of the university
Q 1-6	the family's good opinion of the university
Q 1-7	friends/colleagues' good opinion of the university
Q 1-8	the high position of the university in university rankings
Q 1-9	the future students' high satisfaction with studying at the university
Q 1-10	the quality of the graduates' education

Table 2. University research & teaching strength

Q 2-1	the research and teaching potential of the staff
Q 2-2	the way of conducting classes
Q 2-3	the number of professors in the university
Q 2-4	the number of highly qualified specialists
Q 2-5	the number of employees (practitioners)

Table 3. University promotion and enrolment process

Q 3-1	the effective form of university promotion, such advertising
Q 3-2	the possibility of enrolling on-line
Q 3-3	the date of the entrance exams
Q 3-4	no entrance exams
Q 3-5	the enrolment fee
Q 3-6	the type of the entrance exams
Q 3-7	the form and time of the entrance exams

Table 4. Conditions of study

Q 4-1	the high level of teaching
Q 4-2	easy access to the faculty, e.g. office hours
Q 4-3	the good conditions for foreign languages teaching and the effectiveness of the latter
Q 4-4	the wide range of non-compulsory programmes
Q 4-5	the individual approach to the student
Q 4-6	the stress-free and unproblematic gaining of a university diploma, the fact that optimum conditions for studying have been created
Q 4-7	the extracurricular activities offer reflected in the student life atmosphere
Q 4-8	the friendly atmosphere for studying
Q 4-9	the polite treatment by the faculty and the administrative stuff
Q 4-10	the training courses offer
Q 4-11	the fact that academic seminars and lectures given by well-known figures from the world of science, politics and business are held at the university
Q 4-12	the possibility of getting traineeships and placements
Q 4-13	the opportunity to acquire practical skills
Q 4-14	the possibility of getting a job while studying
Q 4-15	the opportunity to participate in activities consistent with one's interests
Q 4-16	the opportunity to participate in university associations and scientific circles
Q 4-17	the opportunity to acquire academic and research skills
Q 4-18	the possibility of continuing studies at the master and doctoral levels
Q 4-19	the contacts with other universities
Q 4-20	the university infrastructure
Q 4-21	the tuition fees
Q 4-22	the scholarship system
Q 4-23	the organization of study, e.g. no gaps between classes

Table 5. Topographical considerations

Q 5-1	the attractive geographical location of the university
Q 5-2	the closeness to the family home
Q 5-3	the attractiveness of the university city
Q 5-4	the cost of living in the area
Q 5-5	the campus is located in one place

Table 6. Internationalization of studies

Q 6-1	Curricula taught in foreign languages
Q 6-2	the large number of students studying in foreign languages
Q 6-3	the opportunity to go abroad to study at a partner university
Q 6-4	lectures given in foreign languages
Q 6-5	the multicultural academic community
Q 6-6	the large number of teachers from abroad
Q 6-7	access to summer schools
Q 6-8	the good programme and personal collaboration with important foreign partners
Q 6-9	the international exchange of students, facilitated contacts with students abroad

Table 7. Career prospects

Q 7-1	the possibility of acquiring good and solid education
Q 7-2	high prospects for a good job after graduation
Q 7-3	the high percentage of graduates employed upon graduation
Q 7-4	the great opportunity for professional development

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PROPOSED MERGER OF DEA AND ABC METHODS IN ACCOUNTING FOR THE COST OF HIGHER EDUCATION

These changes affect the expectations of managers who feel the need to have more and better information for decision making. Basic knowledge of the management should be the size of revenues and expenses incurred by the activity of an organization. Activity Based Costing has been implemented more and more often in practice. However, it also has several drawbacks. That is why in the literature it is combined with other methods, e.g. with the Data Envelopment Analysis method. The paper is presenting a modification of this combination, tailored for the needs of higher education costing.

1. INTRODUCTION

Modern higher education is functioning in a changing environment, characterized by intense competition, volatile legal, political and social environment and the need for continuous innovation. These changes affect the expectations of managers who feel the need to have more and better information for decision making. Basic knowledge of the management should be the size of revenues and expenses incurred by the activity of an organization. Information provided by traditional costing models are no longer sufficient. That is why Activity Based Costing has been implemented more and more often in practice. However, it also has several drawbacks. One of its drawbacks is the problem of the determination of the consumption rate of cost driver, which is usually taken as equal for all the cost objects, which does not have to correspond to reality. And wrong cost driver consumption rates may lead to wrong conclusions about cost objects, even to rejection of a product which is in fact profitable and pro-

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motion of a product which generates a loss. That is why in the literature it is combined with other methods, e.g. with the Data Envelopment Analysis method. The Data Envelopment Analysis allows to judge objects in the most profitable light for them. Thus, if the cost drivers consumption rates are chosen individually, in the most profitable way for each cost object and this cost object still turns out to be non-profitable, then it is sure that it cannot be profitable. Such an approach has been proposed in the literature. The present paper is presenting a modification of this combination, tailored for the needs of higher education costing.

2. METHODS

2.1. ACTIVITY BASED COSTING METHODS

Method of Activity Based Costing ABC was developed in 1988 by Robin Cooper and Robert Kaplan. This concept is based on the assumption that the direct cause of the costs are action, activities. Implementation of these actions results in consumption of resources, which are a quantitative reflection of the cost[1]. In the literature we can find many examples of cost calculations by ABC method, mostly used as a two-stage model of cost allocation. In the first phase of cost allocation according to the described method, the costs of resources are allocated to separate actions thereby creating a so-called cost pools. To determine the cost of individual pools of activities, the following formula for computing is made[2]:

$$\pi_j = \sum_{s=1}^{S} c_s \cdot n_{js} \quad \text{for} \quad j = 1, ..., J, \tag{1}$$

where:
π_j – the total cost of the j-th action,
n_{js} – consumption rate of the s-resource by the j-th action,
c_s – consumption of s-resource,
S – number of categories of resources.

Identification of the main actions consists of their diagnosis, as well as revealing their sequence and interrelationships. In determining the activities, the level of detail should be chosen in such a way that I will show the important links of cause – effect relationship between cost and cost object, and that it will not lead to excessive complexity and excessive costs of the ABC system. This step is certainly a creative

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[1] PIECHOTA R., *Projektowanie rachunku kosztów działań*, Difin, 2005, pp. 22–23.
[2] HAMBURG C., *Using relative profit san alternative to activity-based costing*, Elsevier, 2004, p. 389.

and innovative one. It requires a team of representatives from different areas of the business entity. Much of their time in the identification of activities should be devoted to the collection of data that can be gathered from official sources, interviews and discussions with staff, surveys, observation and analysis of historical data. The basic source of information on costs is situated in the system of cost accounting entity, including accounting books (diary, ledger accounts and subsidiary ledgers, trial balance and inventory), as well as all the additional information. From the standpoint of activity based costing the information about the structure of costs is very important.

In the second stage, the costs of individual activities are allocated to the cost objects. Cost object is defined as an object for which we collect and count the cost. For example, an object to the cost of higher education may be a student, graduate student, or different forms of education such as lectures, classes, seminars, laboratories, etc. To allocate the costs of specific actions to cost objects, we use the following formula[3]:

$$C_i = \sum_{j=1}^{J} \pi_j \cdot M_{ij} \quad \text{for} \quad i = 1, ..., I, \tag{2}$$

where:

C_i – the indirect costs of the *i*-th product,
π_j – the total cost of the *j*-th action,
M_{ij} – the level of consumption of the *i*-th action by the *j*-th product,
J – number of registered activities.

The problem is that the selection of cost drivers and cost drivers consumption rates for the allocation of resource cost to the activities and of the activities cost to the cost objects is sometimes difficult and what is more, it may change with time. That is why the ABC method is often criticized as too rigid. Also, in the activity based costing there always remains a part of indirect costs, which cannot be applied to cost objects using only a cost causal link between the operation and cost. These cost are allocated somehow, based on some artificially assumed cost drivers, but a big calculation error may occur here[4]. If the cost drivers and the cost drivers consumption rates are not selected and modified properly, the cost information delivered by the ABC method may be misleading (i.e. profitable cost objects may be judged to be non profitable and the other way round). That is why the use of other methods has been proposed to help the decision maker to choose the appropriate cost drivers dynamically, according to the current situation. One of the methods is the Data Envelopment Method.

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[3] PIECHOTA R., *Projektowanie rachunku kosztów działań*, Difin, 2005, pp. 22–23.
[4] PIECHOTA R., *Projektowanie rachunku kosztów działań*, Difin, 2005, pp. 22–23.

2.2. DATA ENVELOPMENTS ANALYSIS METHODS

Method of Data Envelopment Analysis DEA was first presented by A. Charnes, W. Cooper and A. Rhodes in 1978. It originated from the concept of productivity defined as the ratio of the single effect of a single effort. The above authors have used the relationship to the multidimensional situation where we have more than one effort, and more than one effect[5]. Measurement of performance in accordance with the presented method can be obtained by using the following formula[6]:

$$e = \frac{\sum_{r=1}^{S} \mu_r EFFECT_r}{\sum_{I=1}^{M} v_i INPUT_i} \tag{3}$$

where:
- e – efficiency,
- M – number of inputs,
- S – number of effects,
- v_i – the weight determining the validity of individual effort,
- μ_r – the weight determining the validity of individual effect.

In the DEA method of analysis the objects are decision-making units, so called DMU. However, the subject of analysis is the productivity of those units. Determination of the efficiency of DMU using this method for each one of them is the solution of linear programming problem in which the ratio of outcomes to inputs is maximized with given constraints. It makes it possible to identify the strengths of the individual DMU's and the prior knowledge of weights defining the importance of individual effort and results is not required. Since the DEA method is a nonparametric method, it is also not required to determine the functional dependence between inputs and outcomes. This method allows to determine the border efficiency curve, which includes all of the most efficient units, and their effectiveness is 100%. Units that are below the curve are inherently inefficient. Their scope of improvement is determined by comparing the results achieved by efficient units[7].

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[5] NAZARKO J., KOMUDA M., KUŹMICZ K., SZUBZDA E., URBAN J., *Metoda DEA w badaniu efektywności instytucji sektora publicznego na przykładzie szkół wyższych*, Badania Operacyjne i Decyzje, nr 4, Wydział Zarządzania, Politechnika Białostocka 2008, pp. 91–103.

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Two criteria are important in creating models of the DEA: the orientation of the model and type of scale effects. Depending on the orientation of the model, the technical efficiency of input-oriented or technical efficiencies result-oriented is calculated. The purpose of this first is to minimize expenditures while maintaining the invariant results, while the second one is to maximize results while maintaining the invariant inputs. The second criterion defines the assumptions about economies of scale have been adopted in the model (variables, constants, or not increasing)[8]. The important thing is that each DMU is shown in the best possible light, thus those DMU's which are evaluated as poor certainly are so.

3. COSTING MODEL BASED ON A COMBINATION OF ABC AND DEA

In this part of the work the way of connecting the concept of activity based costing with the concept of data envelopment analysis is presented.

Suppose k is a product, but $k = i' \in \{1, \ldots, I\}$. In determining the optimal (from the point of view of the product) total consumption rate of the j-th action for k-th product, $\pi_{kj}*$ ($j = 1, ..., J$), the following objectives seem to be reasonable. First, that the k-th product cost should be covered by the revenues of this product. If this condition is not met its production is not profitable and the product should be eliminated. Secondly, it is important to obtain the highest possible profit. Therefore, when all products are evaluated on the basis of their $\pi_{kj}*$, the difference between the profit from k-th product and the greatest profit potential to reach out to all products should be as small as possible. Thirdly, the optimal size of activity cost drivers is obtained when the profit calculated on their basis is the highest. All the objectives to which we seek must be optimized. You can define them as follows[9]:

$$\underset{\pi_{kj},\Delta_k,\delta k}{opt}{}^{lex}\left\{\min \Delta_k, \min \delta_k, \max AP_k\left(\pi_{kj}\right)\right\}, \qquad (4)$$

Restrictive conditions are:

$$AP_k\left(\pi_{kj}\right)+\Delta_k \geq 0, \qquad (5)$$

$$AP_k\left(\pi_{kj}\right)- AP_i\left(\pi_{kj}\right)+\delta_k \geq 0 \ \text{ for all } \ i =1, ..., I, \qquad (6)$$

[8] SZYMAŃSKA E., *Zastosowanie metody DEE do badania efektywności gospodarstw trzodowych*, Journal of Agribusiness and Rural Development 2009, pp. 251
[9] HAMBURG C., *Using relative profit san alternative to activity-based costing*, Elsevier 2004, pp. 389

$$\pi_{kj} \geq \varepsilon \quad \text{for all} \quad j = 1, ..., J, \tag{7}$$

$$\Delta_k, \delta_k \geq 0. \tag{8}$$

where the variables π_{kj}, are the product-specific consumption rates of cost driver j, there variable $AP_i(\pi_{kj})$ represents the product i's absolute profit on the basis of the cost driver rates π_{kj} and the absolute profits are calculated using the following equation:

$$AP_i(\pi_{kj}) = R_i - \sum_{j=1}^{J} \pi_{kj} \cdot M_{ij}, \tag{9}$$

where variable Δk is used to determine product k's gap in covering its activity-based cost when being evaluated on the basis of π_{kj}, while variable δ_k is the difference of the product k's profit and the biggest profit possible to achieve among other products, when all products are evaluated on the basis of π_{kj}. The variable ϵ is positive, which is roughly equal to zero[10].

The goal function means that the three objectives must be optimized in the in the lexicographic order. First, the objective function is to minimize the variable Δk witch given constraints. Then the objective function is to minimize the variable δ_k while he minimum value of the variable Δk obtained in the earlier stage of the counting model is to be kept. At the end, the objective function will be to maximize profit $AP_i(\pi_{kj})$, taking into account new restriction, i.e. the minimum value of δ_k. To determine the optimal product-specific cost drivers rates $\pi_{kj}*$, for all I products, the program (4)–(8) must be solved separately for each product[11].

4. EXAMPLE

Theoretical assumptions about how to connect ABC and DEA methods are here illustrated with a practical example from the university costing area. Let us suppose the analysis of processes and activities has been carried out in a technical college In this paper we focus on one of the numerous process – Conducting classes. This process is composed of the following activities[12]:

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[10] HAMBURG C., *Using relative profit san alternative to activity-based costing*, Elsevier, 2004, pp. 389.

[11] HAMBURG C., *Using relative profit san alternative to activity-based costing*, Elsevier, 2004, pp. 389.

[12] Activities describing the process – conducting classes is from – Kuchta D., Ząbek S., *Measuring the cost of activities performer at the University*, International Conference of Education, Research and Innovation, Madrid 2010.

  − implementation of the course in the lecture form (W),
  − implementation of the course in workshop form (P),
  − implementation of the course in exercise form (C),
  − implementation of the course in the laboratory form (L),
  − implementation of the course in the seminar form (S).
Cost objects are, for example, students from selected departments, namely:
  − students from the Department of Computer Science and Management (IIZ),
  − students from the Department of Chemistry (CH),
  − students from the Department of Architecture (AR),
  − students from the Department of Mechanical Engineering (ME),
  − students from the Department of Electronics (EL).

Table 1 shows the results of applying the traditional method of activity-based costing, having five activities, distinguished above, as well as five products. Let us assume activity W is allocated to the cost objects by means of one cost driver (e.g. number of hours), activity P uses another cost driver (number of projects to be performed by the students), activity C has the cost driver "number of groups", activity L uses the cost driver "number of units of certain type of material used", activity S uses the cost driver "number of themes to be treated". We also assume to know drivers consumption, given in Table 1: e.g. IIZ students use 30 number of hours of the lecture, those students had to perform 60 projects, they were divided into 15 groups, they use 30 number of units of certain type of material and those students had to prepare 30 number of topics for discussion.

In the conventional Activity Based Costing the cost drivers allocation rates are supposed to be the same for each cost object, i.e. it is assumed (Table 1) that one lecture hour costs 0,02, one project costs 0,01, one group costs 0,01, one material unit costs 0,05 one theme costs 0,01, no matter which department is concerned. This assumption does not have to true. In some departments groups may be larger or smaller, themes more or less difficult etc. However, this is how conventional Activity Based Costing works. The results are presented in Table 1. Column 7 contains the products (cost object) activity-based cost. Columns 8 give the products (cost object) revenues (from students fees and/or a subvention from the Ministry of Education) and the last column give absolute profits for each cost object.

Table 1. Conventional ABC

Product	Cost driver consumption of					ABC	R	AP
	$\pi_1=0,02$	$\pi_2=0,01$	$\pi_3=0,01$	$\pi_4=0,05$	$\pi_5=0,01$			
IIZ	30	60	15	30	30	5,85	40	34,15
CH	30	30	60	15	15	3,75	30	26,25
AR	60	30	30	15	30	5,55	35	29,45
ME	30	30	15	15	15	3,30	40	36,70
EL	30	15	60	60	30	7,35	40	32,65

Table 2 presents the results of calculations based on assumptions derived from a combination of ABC and DEA methods. Products relative profits have been calculated by using equation (4)–(8). We still need the cost driver usages shown in Table 1. However, the consumption rates, i.e. the costs of one lecture hour, of one group, on theme etc. have been calculated separately for each cost object thus for each college department. What is more, they have been calculated using the most favorable assumptions for each department. Thus no department may claim that they have been treated in an unjust way and their cost have been over estimated.

Table 2. Relative profits

Product	Product-specific cost driver rates					ABC*	R	AP*
	$\pi_{i1}{}^{*}$	$\pi_{i1}{}^{*}$	$\pi_{i1}{}^{*}$	$\pi_{i1}{}^{*}$	$\pi_{i1}{}^{*}$			
IIZ	€	€	€	€	€	0,165	40	39,835
CH	€	0,102	€	0,066	0,062	5,053	30	24,948
AR	€	€	0,666	€	€	20,01	35	14,900
ME	€	€	€	€	€	0,105	40	39,895
EI	€	€	€	€	€	0,195	40	39,805

Some products choose cost driver rates of $\in$ for some of the cost drivers, this means that product uses this cost driver extensively. That means the cost driver is critical for the product – if the department, trying to show itself in the most favorable way, set the corresponding allocation rates to almost zero.

Based on the calculation results obtained using the traditional model of activity-based costing, which are presented in Table 1, the best, that is with highest profit, is the students from the Department of Mechanical Engineering (ME). Subsequently, the best are the students from the Department of Computer Science and Management (IIZ), students from the Department of Electronics (EL), students from the Department of Architecture (AR) and the worst is the students from the Department of Chemistry (CH).

Comparing the results from Table 1 and Table 2, where the costs were calculated using the method of Data Envelopment Analysis we can see that the worst – the least profitable student is the student students from the Department of Architecture (AR).

In the market, new operators and the existing ones derive new forms of education. They provide more up to date courses and specialties. In addition to fixed-cycle programs colleges also offer engineering degree, undergraduate, graduate in full time or part-time. Changing market conditions in higher education mean that they now face the task of competing for students, research projects with universities in Europe and the world, and for the teachers. In the case of universities, to seek the relationship between the cost of doing business and their funding mechanisms, and mechanisms of governance and accountability of the effects of its activities is extremely difficult. The problem of accounting for costs of institutional activity occurs not only in Poland but in many countries. Often there are difficulties due to the limited autonomy of univer-

sities in conducting financial management. In some cases the problem may be an accounting system, inappropriate, inadequate actions or lack thereof.

Whatever the difficulties occurring in different countries in accounting for the cost of higher education are, actions are taken to improve existing solutions, to introduce new ones. Colleges and universities are aware of the fact that changes in the financial system will lead to more effective management than ever before. In addition, a new way of costs accounting with greater precision and accuracy make that research funding agencies, through the accrued image of costs, may be inclined to look more favorably on the actions taken by the university and will cooperate with them.

Basic knowledge for the management of organizations should contain the size of their costs and the information about processes in the course of which the cost arises. Information provided by traditional cost models, i.e. the full cost accounting and cost accounting variables are not always adequate to the needs of decision-making process. Managers aware of this fact express a deep conviction about the need to implement such cost models, which will provide complete and accurate information. Currently, the management for institution of higher education is not possible without establishing a competitive range of courses, and its creation is not possible without information about the cost of teaching from the specificity of individual institutions, departments, faculties, curricula. Knowledge of the costs of education bachelor, master, engineer, doctoral student becomes important. Equally important is the knowledge of the cost of courses given in the course of study to demonstrate differences in the cost of various forms of teaching such as lectures, classes, seminars, laboratories and others. The cost of training the student should take into account all the ways through his/her education, starting with the recruitment and ending at the end of education.

Application of activity-based costing for higher education will allow to obtain information such as[13]:
- the total cost of the educational process,
- the cost of training the student depending on the individual departments, faculties, specialties, and over time (years, semesters),
- the cost of different forms of education such as lectures, exercises, seminar, laboratory,
- the total cost of implementing educational program,
- calculation of costs used for teaching space,
- the level of unused space teaching,
- the level of unused capacity of teaching staff,

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[13] KUCHTA D., BOJNOWSKA A., PARKITNA A., *Application of activity based costing at a Polish university* (in Polish), Konferencja z cyklu rachunkowość a kontroling, Systemy zarządzania kosztami i dokonaniami 2010.

- the cost of research, which is extremely important in the case of grants for these studies,
- cost of services rendered to the industry.

Application of activity based costing in higher education can be helpful in planning the budget, and effectively promoting the process of managing it. Information obtained here can be used in the analysis of variations occurring between plan and reality. Activity based costing contributes to a better understanding of how the service works, because it provides information on the location and cost reasons. However, the implementation of this method may be linked to some difficulties, among others:

- a diversion of courses,
- high complexity of certain activities related to the learning process,
- complicated rules for assigning certain costs to separate actions.

Implementation of activity based costing in universities requires not only changes in the calculation procedure used so far, but also changes in the organization of these units. Activation of the ABC requires collecting and processing vast amounts of data. The entire procedure is time consuming and extremely complicated. Moreover, the process of data collection is cost consuming, because it constantly needs to be updated. In connection with the implementation of new cost accounting system, people responsible for the implementation may encounter resistance from employees, which can lead to a slowdown of work. Resistance to change has a source in, *inter alia*, the tendency to fear of novelty, lack of knowledge of principles, a reluctance to learn, dislike of the person responsible for the changes made, so it's important to raise awareness of the need for change. Among the problems associated with the introduction of the ABC model in particular, talking about the need to adapt the accounting system, the use of additional activities for measurement, analysis is especially important. All these changes are associated with costs.

Despite the disadvantages of activity based costing, the model generates more reliable, accurate information in relation to traditional models of cost accounting.

Activity based costing reflects the structure of costs incurred by operators to a higher degree than traditional models. It provides not only information about the type and amount of resources used, but also allows to investigate factors affecting them. The calculation is based on actions, and *inter alia*, allows for more accurate determination of the cost of services provided. Modernization of activity based costing methods involving the use of data envelopment analysis to determine allocation rates deserves attention because it eliminates some disadvantages of standard methods of activity based costing and the difficulties in choosing a suitable cost drivers rate. Both the activity based costing and the method of data envelopment analysis are effective tools not only supporting the management, but also the costs measuring.

5. CONCLUSIONS

The functioning of higher education in a changing environment forces us to seek new solutions for cost accounting and cost reduction. Model of activity based costing proposed here will provide information on the type and amount of resources used. It will also enable an analysis of activities performed by the university and cost objects generated by universities, making it possible to eliminate the inefficient ones. But what is most important, it will allow for a more accurate determination of the cost of services provided. The combination of the methods Activity Based Costing and Data Envelopment Analysis deserves attention because it allows a wider and more correct use of the ABC at universities by eliminating the drawbacks of the standard ABC approach.

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[3] KUCHTA D., BOJNOWSKA A., PARKITNA A., *Application of activity based costing at a Polish university* (in Polish), Konferencja z cyklu rachunkowość a kontroling, Systemy zarządzania kosztami i dokonaniami 2010.
[4] NAZARKO J., KOMUDA M., KUŹMICZ K., SZUBZDA E., URBAN J., *Metoda DEA w badaniu efektywności instytucji sektora publicznego na przykładzie szkół wyższych*, Badania Operacyjne i Decyzje, No. 4, Wydział Zarządzania, Politechnika Białostocka, 2008, pp. 91–103.
[5] PIECHOTA R., *Projektowanie rachunku kosztów działań*, Difin, 2005, pp. 22–23.
[6] SZYMAŃSKA E., *Zastosowanie metody DEE do badania efektywności gospodarstw trzodowych*, Journal of Agribusiness and Rural Development, 2009, p. 251.

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THE NEW LOOK FOR COST CALCULATION
OF RESEARCH ACTIVITIES IN THE UNIVERSITIES

In connection with many economical changes, the higher education sector is facing necessity of adjustment to the market economy conditions. Therefore, efficient and effective management became the necessity.

The authors of this study propose application of the management accounting tools, which is cost account of the activities, as the method constituting information basis for the managers. The method being presented should serve valuation of the products of research works, supporting thereby the process of rational application of the financial resources through increase of effectiveness of the performed tasks. The study includes also the manner of conducting researches connected with the attempt to apply the cost account of the activities at the university and initial results thereof.

1. INTRODUCTION

In relation to many economical, system and technological changes, higher education sector is facing demand for radical changes, which will enable universities performance of the contemporary civilization needs and simultaneously adjustment to the conditions of market economy.

New possibilities of development offered by globalization require efficient and effective management. There is a need in the higher education sector to apply management methods based on the solutions, which are proven as efficient in the market enterprises. Reliable management information in the hands of qualified decision-makers, constitute the basis for achievement of success.

While applying the process approach constituting the basis of treatment of the university, as economical existence, the research and development process shall be distinguished, as one of the four main processes carried out in that organization. The

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authors of this study propose application of the management accounting tool – cost account of the activity ABC as the method constituting information basis for the mangers – exactly within that scope. The method being presented should serve valuation of the research works products – and support the process of rational funds application, as well as increase effectiveness of the executed tasks. However, it should be stressed that implementation of ABC itself is not easy and shall require adjustment of information technology infrastructure within the scope of recording and costs settlement, as well as modification of the processes carried out inside of the entity. The necessity to adjust methodology to the specificity of activity of the higher education sector and services provided by them, as well as information requirements of the management staff shall not be forgotten in this case. This study includes possibility to apply the activity cost account at the universities considering in particular the scientific research field. The special tool based on application of MS Excel and VBA has been established for the requirements of analysis of replies obtained from the survey form.

2. CONTEMPORARY CHALLENGES
OF THE UNIVERSITIES

Dynamic changes of the social and economical systems, which took place in the last two decades have led to increase of significance of the education acquired at the universities.

Increasing demand of the international labor market for highly qualified specialists, which constitutes result of the factors, such as: transformation of the economy based on production into economy based on knowledge, increasing complexity of economical processes and sudden technological progress in all areas of life led to dynamic development of the education services market.

In the period of last twenty years the number of universities in Poland increased threefold from 131 institutions in the year 1991 to 461 in the year 2009, wherein 326 institutions constituted private universities and the enrollment rate in the higher education sector in the analogical period increased fourfold. This ratio constitutes relation of the number of learning persons to the entire population in the particular age group – from 18 to 24 years for higher education – and in the academic year 2006/2007 amounted in Poland 49,9%[1].

Those data reflect how material role constitutes presently higher education market: in the economy – providing qualified specialists; in the social and culture life, enabling youth education which is the basis of future advantages; finally for the scientists, creating possibility to conduct research and development works, which results should

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[1] Small Statistical Yearbook – the Statistical Publications Establishment [Zakład Wydawnictw Statystycznych], 2010, str. 233, http://orka2.sejm.gov.pl/IZ6.nsf/main/5F9E7C02 (data pobrania 2010-07-17).

contribute to improvement of quality and effectiveness of business processes construed as entirety of the activities carried out in the economy.

Visible evolution of the educational services market reflects inter alia increasing number of new faculties, more numerous manners of knowledge acquisition from the studies of first, second and third degree through offers of post-graduate studies finally to e-learning solutions.

Analyzing the reasons of increase of the educational services market many factors may appear of external nature, determining strategies of activities in the sector of higher education, as for instance:

− achievement of so called Lisbon goal, constituting supplement of the provisions from Lisbon, which assumes achievement and maintenance until year 2010 of the expenditures for researches and development on the average level 3% of the Gross Domestic Product, on the assumption of minimum 2/3 of the financial share of private sector, the figure below presents division of resources for researches and development in consideration of the sources of financing thereof in the European countries in the year 2007.
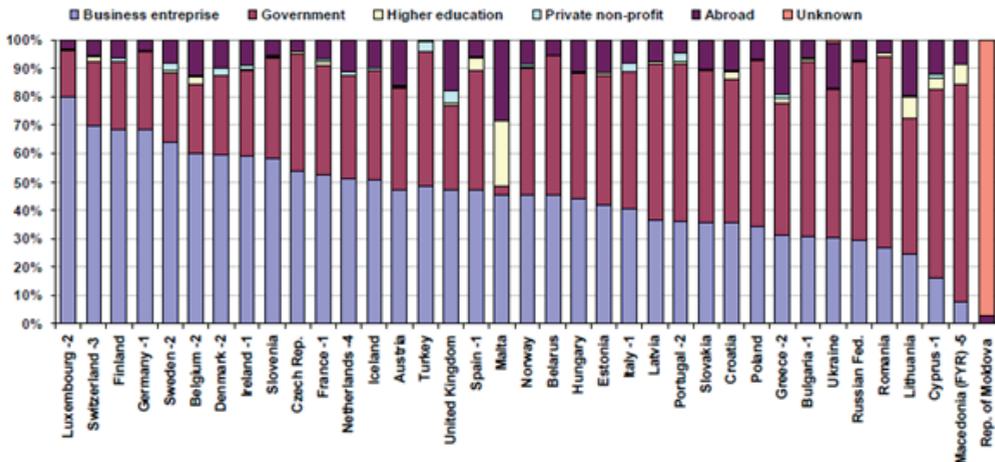
Fig. 1. Gross Domestic Expenditure on R & D by source of funds in 2007.
Source: UNESCO Institute for Statistics, Report: *A global perspective on research and development*

− increase of the expenditures for higher education, enabling performance of research and development works with material share of private sector (according to the Strategy from Lisbon, approximately 65%), providing guarantee of commercialization and application of researches results in the economy. Potential of co-financing research and development activity may be noticed on the example of economies constituting the top world leaders of growths in the recent years as for instance: China. Figure 2 presents the level of changes in expenditures for

research and development in the relation to the Gross Domestic Product in the breakthrough of the years 1996–2007.
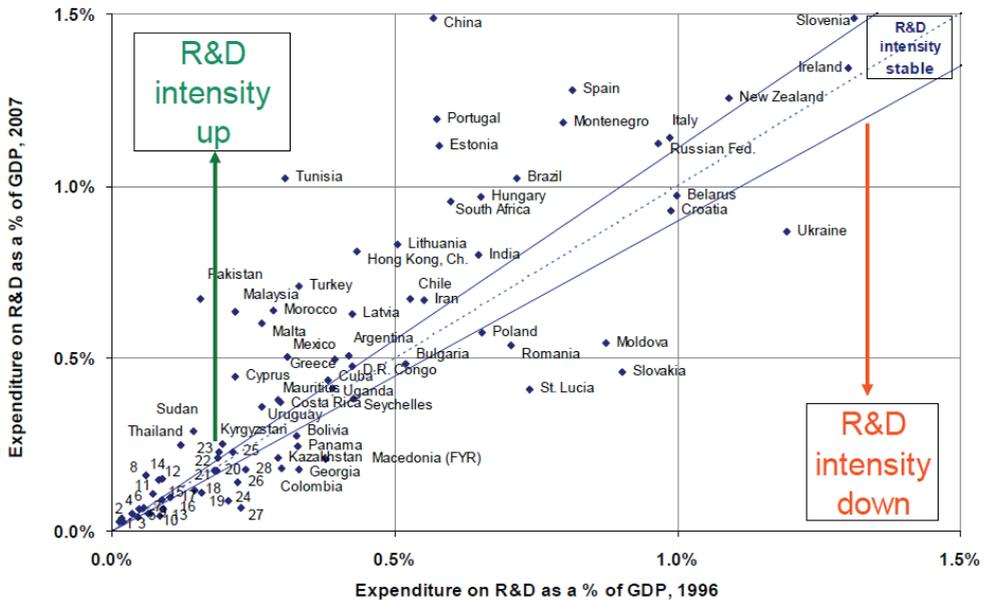
Fig. 2. Gross Domestic Expenditure on R&D as a percentage of GDP, 1996 and 2007 countries with R & D intensity below 1.5% in both years.

Source: UNESCO Institute for Statistics, Report: *A global perspective on research and development*

   − popularization of the studies, which was caused by awareness increase of the society and possibilities which were created by new private universities, including paid forms of education.

In the academic year 1990/91 the number of students amounted almost 0,40 million of students and achieved fifteen years later the value almost fourfold higher and the highest in the previous history of Poland on the level exceeding 1,95 million.

Systematic decrease of the number of students has been recorded since that time, which deepened financial crisis in the short period and hindered financing paid studies, however in the longer period it is strongly conditioned on demographic factors.

Systematic decrease of the number of students is predicted now (up to 55% of value from 2005 in 2025[2] and beginning thereof may be observed in figure 3.
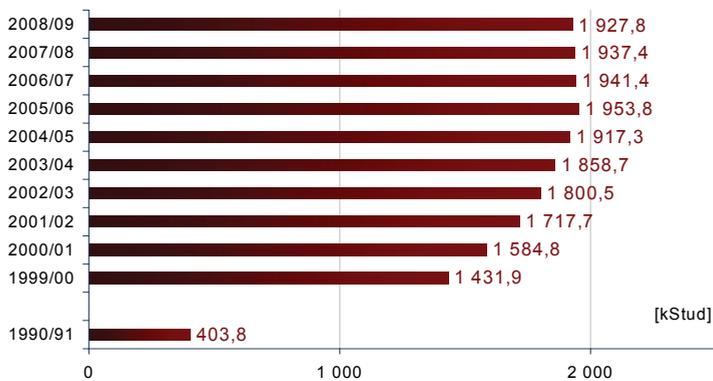
Fig. 3. Number of students in Poland.
Source: The study on the basis of data from the Central Statistical Office the need of effective use
of resources caused by difficult economical situation and decreasing number of services recipients
which is directly put into the strategy of universities management

Changes of financing sources of scientific researches visible in the majority of the European economies, increasing value thereof in relation to the Gross Domestic Product and systematic limitation of the barriers of education abroad, including numerous grant programs support popularization on the market and internationalization of the higher education sector –in the year 2006, globally outside of borders of the native country 2.9 million students were studying[3].

This situation shows how important role begins to play effective university management which, being treated as "economical existence" should participate in creation of "scientific and research chain of values"[4].

Understanding of the essence of university activity and the role it plays in the contemporary economy allows to approve deficiency of differentiation in the management rules of entities geared towards profit achievement and institutions of non-profit purpose[5].

Increasing number of relations connecting economical entities with the university research institutes, in order to conduct and commercialize later results of research and development works supports the need to transform the manner of management into the model enabling achievement of the optimal quantity of advantages for both parties.

Market demand for innovation which might constitute the grounds for rivalry and competitive advantage supported by subsidies and financing of research and develop-

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[3] BOJNOWSKA A., URBAN M., *Assumptions of the strategy of the Technology University of Wroclaw*.
[4] UNESCO Institute for Statistics, Raport: *A global perspective on research and development*, http://www.unesco.org/science/psd/wsd07/Fact_Sheet_2009.pdf
[5] Australian Department of Education, Training and Youth Affairs (DETYA).

ment works constitutes the basis of development and effective co-existence of the suppliers and recipients of that process.

2. INFORMATION REQUIREMENTS
FOR THE UNIVERSITY MANAGEMENT NEEDS

Financial systems existing on the universities – which is broadly emphasized in the literature – first of all aimed at detailed reporting addressed to the funds providers.

Presented financial data serve first of all for accomplishment of the goals, resulting from the rules of law governing activity of the universities and external recipients. Their usability in taking decisions, which might improve quality of economy management is significantly limited.

Cross sections, in which those data are disclosed are extensively general and do not enable legible following of undertaken initiatives results. The reports are aimed at presentation of the historical events and they do not sufficiently support processes of forecasting and planning of financial results of the conducted activity. Material and financial plan constitutes presently the only report within the financial scope of the public university.

It is the statement, which defines division of the tasks and resources into the particular types of activity and organizational entities of the university, as well as the list of revenues and costs from the basic operating activity, which include results achieved in the didactic and research activity, being separated economically – in accordance with paragraph 5 of regulation of the Council of Ministers on the detailed rules of financial economy of public universities.

The legislator does not disclose detailed rules of records and settlement of the costs. Provisions of the regulation provide authorities of the university quite extensive freedom in conducting costs account, even without mentioning issues of settlement keys concerning indirect costs.

Such information system is decisively insufficient. Dynamic economical changes, which took place in several years, caused material changes in the higher education sector. The process of transformation commenced by universities from centrally managed to partially autonomic is similar to that one, with which enterprises dealt with many years ago in the course of transformation from centrally managed economy into free market economy. Previously university market and presently students market, characterizing itself with limited – decreasing quantity of recipients and wide didactic offer, managed by numerous entities which arose *inter alia* in the period before crisis bull market, provides new challenges.

Similarly, as in case of commercial enterprises, survival of higher schools on the market in the slow down period may be ensured by effective and efficient management processes. Their basis should constitute reliably elaborated information man-

agement systems providing detailed knowledge *inter alia* concerning sources and amounts of incurred costs and achieved revenues.

It enables immediate reaction to the signals coming from the environment and constitutes undoubtedly strong element of the competitive advantage being developed. Nowadays, innovation also constitutes material role. In the universities, it is not only development of information technologies applied by the students, but also development of information didactic and scientific infrastructure applied by the employees. Furthermore, development of the universities shall not be possible without effective management by the managers based on reliable management information processed by integrated information systems. University management becomes similar in higher degree to management of the enterprise conducted in the market conditions. The following issues are material, including *inter alia*: planning, costs account, promotion, advertisement and other elements affecting strategic and operating advantage in the areas carried out by the university.

Process approach becomes the basis of treating university as economical existence, in which mapping of processes carried out in the organization becomes the basic element. The map of processes is created in such way, which outlines the course of processes across functional sections of the organization. Approach from the perspective of processes enables initiation of the programs, increasing effectiveness of the conducted activities – from simple elimination of unnecessary activities, through transformation of ineffective or inefficient ones to entire reorganization of the tasks performance. Activity of the universities in general approach may be divided into four main groups of conducted processes – Figure 4. The following processes shall be included:

1. didactic,
2. scientific and research,
3. administrative,
4. supporting.

Fig. 4. The basic groups of processes carried out at the universities.
Source: own study

The first group of processes includes broadly understood didactic activity considering paid and unpaid forms of education addressed to the students, graduates, employees of the economy etc. This activity is carried out through paid and "unpaid" forms of education, during studies, post-graduate studies, trainings, workshops, conferences and others.

Scientific and research processes constitute entirety of works carried out at the university for the requirements of knowledge acquisition. They are used for science development, support of the economy in innovative solutions, increase of the education quality etc. Administration processes of the university are aimed at organization of the didactic and scientific activity with application of available resources[6].

The last group of supporting processes includes all those activities which could not been subordinated to any previous groups. Particularly material role in the management process of the university constitutes scientific and research field. Entirety of the globally carried out activities in this field in 2007 exceeded 200 milliards Euro. Figure 5 presented below presents expenditures for research and development activity in the relation to the Gross Domestic Product in 2007 with division into particular countries.
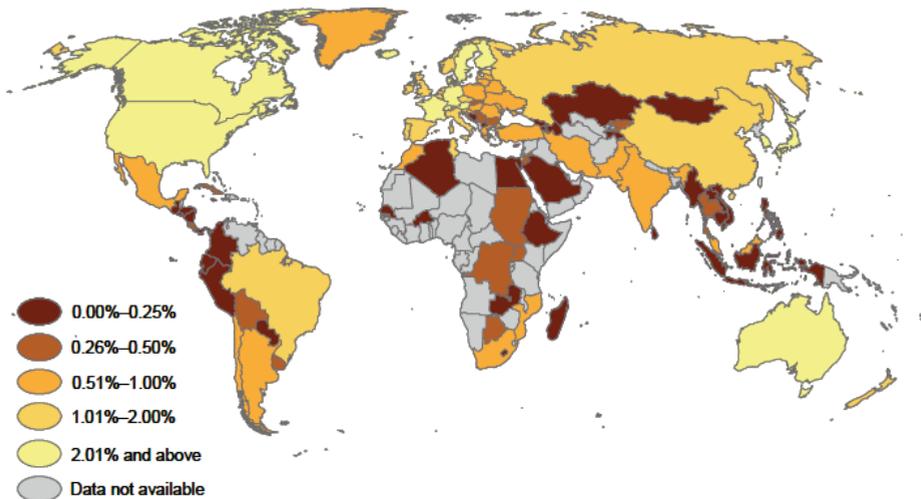
Fig. 5. Gross domestic expenditure on R&D as a percentage of GDP in 2007.
Source: UNESCO Institute for Statistics, Report: *A global perspective on research and development*

Table 1 includes GDP values achieved by selected economies in 2007. The amounts presented in milliards of Euro show how extensive market constitutes research and development area and how material role reliable management information has, creating the basis for efficient and effective management.

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[6] Australian Department of Education, Training and Youth Affairs (DETYA).

Table 1. GDP of selected regions in 2007

Region	GDP in 2007 (mld_EUR)
EU-27	12 276,20
US	10 094,50
Japan	3 197,60
China*	1 787,30
Russia*	610,60
* year 2005	
Total	27 966,20

Source: http://europa.eu/abc/keyfigures/tradeandeconomy/production/index_pl.htm

Increasing expenditures for scientific and research activity and numerous sources of financing thereof (subsidies from the state budget, funds from the economy, subsidies from the European Union, research and development grants etc.) cause, that effective application thereof becomes more and more difficult. Management accounting tools applied in the course of assessment and improvement of effectiveness of enterprises processes should constitute the basis of effective management also in case of scientific and research activity. Large quantity of performed processes may be defined therein, leading to creation of the specified "products" – the results of conducted works. Calculation of the costs according to ABC method (Activity Based Costing) is based on the processes and activities included therein. The reply to malfunction of traditional models of costs account constitutes ABC method and management method ABM (Activity Based Management) based on its basis. Costs account of the activities has already been transferred to the educational environment. Its applications may be found in such countries, as: Australia, United Kingdom or USA. The wide scope of application of the discussed method concerns especially Australia. Australian government found in 1998[7], that hitherto manner of operation of the public universities is not effective. They have to function more efficiently and effectively. The project[8], aimed at determination of appropriate costs calculation methods being consistent with the imposed conditions, constituted the result of those conclusions Two reports[9] were prepared on the basis of those implementations, providing information concerning application of the costs account in the educational environment or on the level of entire university or in the particular areas of its activity. However, the first interest in

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[7] Australian Department of Education, Training and Youth Affairs (DETYA).

[8] Sponsored study to develop a costing methodology for Australian Higher Education Sector.

[9] *A Study to Develop a Costing Methodology for the Australian Higher Education Sector* – 2000 and *A Study to develop a costing methodology for Library and Information Technology Activities for the Australian Higher Education Sector* – 2001.

costs account of the activities concerning universities may be found in the United Kingdom. The researches connected with operations of the university and potential application therein of the method in question were out already in 1993. Any institution has not negated application of the costs account of the activities due to the reasons such as unreliability or ineffectiveness of the activity in the university environment in the year 1998. The account has already been implemented in nine units, but further 16 intended to do this[10]. Application of the account may be found in the United States. Any application of the cost account of activities at the universities refer to foreign countries. Therefore, those solutions are not unadjusted automatically to the Polish conditions, due to other financial and accounting systems, budget systems or specificity of operation (certain activities and processes related therewith carried out at the universities differ from those in Poland).

Application of that method in the Polish public universities practically does not exist. It is proven practically, because of lack of the publications and practical experiences within this scope. However, efforts have been undertaken in this scope at the University of Technology in Wrocław[11]. Application of the activities costs account for valuation of the scientific and research process constitutes complete novum. It's description is shown in the next paragraph.

3. PROPOSAL OF THE MANNER OF VALUATION AND ASSESSMENT OF THE RESULTS OD RESEARCH WORKS AT THE UNIVERSITIES BASED ON THE ACTIVITIES COST ACCOUNT

In the method of activities costs account the resources (that is costs) are assigned to the activities and further costs of the activities shall be settled for the products or services or other cost items proportionally to application of the activities. Therefore, the starting point for application of that concept of costs settlement constituted identification of the effects of research process activity, as well as activities leading to achievement thereof and assigning to them appropriate costs through used resources. That manner of proceedings may be presented in figure 6.

In the first place of application of the activity costs account for valuation and assessment of the effects of research works the attention was focused on preparation of the tool, which will enable examination of the scientific and research process – in respect of resources consumption and connection of executed activities with their

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[10] CROPPER P., COOK R., *Activity-Based Costing in Universities – Five Years On*, Public Money & Management (April–June 2000).

[11] The project *The method of calculating costs in the universities using the activity based costing*, no. 47623, National Centre of Science and Development, Poland. It is executed by team of scientists: Bojnowska A., Klaus-Rosińska A., Kowalski M., Kuchta D., Parkinta A., Ryńca R.

products (which constitutes modern and unique approach). The survey form became that tool and its purpose was: identification of the activities, products of activities and resources being necessary for performance of the activities within the scope of scientific and research activity. The works on survey form were divided in time and conducted on seminar meetings with application of the following methods: literature analysis, own experiences of the research team members, brainstorm and common reflections.

Fig. 6. Activity Based Costing model.
Source: own study

The main research material constituted information collected on the first stage of research works that is in the course of the talks, conducted with representatives of all faculties of the University of Technology in Wrocław within the scope of characteristics of the basic scientific and research processes carried out in various fields of science.

The survey form was consulted with the specialist on creation of such tools and social psychologist. The survey form was sent several times tentatively to the selected, small group of employees of the Technical University of Wrocław, in order to control correctness thereof, legibility of the provisions, as well as precision within the scope of achieved replies. The following items have been included in the survey form among cost items that is the products constituting effect of the research activity:

1. Publication.
2. Conference speech.
3. Poster.
4. Prototype.
5. Patent.

6. Computer program.
7. Implementation of the developed concept.

Respondent obtained possibility to indicate other. Simultaneously, the questions were asked for frequency of their appearance and here the following phrases could be used: *never, occasionally, often, very often, always or almost always.*

1. Review – systematization.
2. Description of applications/implementation of well known concepts.
3. Description of conducted experiments, results of the experiments.
4. Description of researches and other results than experiment.
5. Case study.
6. Presentation of new theory/method.
7. Popular scientific type.

Respondent obtained possibility to indicate others. Simultaneously, the questions were asked for frequency of their occurrence and here the following phrases could be used: *never, occasionally, often, very often, always or almost always.*

Activities, which were included in the survey form, being used for conducting research activity are the following:

1. Analysis of the existing state of knowledge.
2. Development of the new concept or modification of the existing one.
3. Planning/preparation of researches.
4. Conduct of researches (laboratory, survey, territorial and other researches...)
5. Analysis of the results of conducted researches (for instance: statistical)
6. Verification/implementation of the obtained results.
7. Summary of the works, presentation of the results (for instance: preparation of publications).
8. Correction of publication after review.
9. Preparation of the scientific studies review.

In this case the respondent also obtained possibility to indicate other activities.

Scientific employees were also asked for frequency of those activities occurrence and here the following phrases could be indicated: *never, occasionally, often, very often, always or almost always.* In this case respondents also took position with respect to labor intensity of the performed actions. The next part of the survey form included questions on the types of resources and frequency of application thereof, used for performance of the activities, serving for the effects of scientific activity, that is:

1. Personal computer.
2. Specialist computer software (other than standard office package, for instance MS Office).
3. Data bases made available by library of the university or generally available.
4. Other databases, additionally paid.
5. Laboratory in Your unit.
6. Laboratory outside of Your unit.

7. Reagents and other laboratory materials.
8. Devices from industry.
9. Computer centers (clasters).

The respondent obtained possibility to indicate others.

Important issue mentioned in the survey form was also the matter of formal assessment of the scientific work effects by employees. The questions were asked, whether scoring (value) of the publication according to official list of the Ministry reflects outlay of work, rank, value of publication and whether the system of internal publication assessment does exist in the organizational entity and whether the need of its existence really exists.

Upon final acceptance, verification and testing of research tool, the survey form was distributed among scientific and didactic employees in the electronic form through the web site www: http://abc.pwr.wroc.pl/_index.php [12].

This tool allows to collect results of questionnaire in the form of transparent report enabling presentation of data both in the numerical (values, percentages), as well as in graphical form (column and circular charts). Figure 7 presented fragments of report concerning results of the survey form.

Fig. 7. Part of the Report of questionnaire's results.
Source: own study

On the basis of 91 replies to the question on the time percentage of work designated for research and scientific activity, no less than 53 persons said, that this time should not exceed 30% of the total time of work and almost half of them (24 persons) replied, that it was not more than 10%. The table 2 below presents results of the re-

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[12] Text version of the survey form does exists on 22nd March of 2010, which is verified by the selected group of respondents. It has been distributed among employees of the Information Technology and Management Faculty since May of 2010.

plies to the question, concerning activities and frequency of execution thereof in the scientific and research work.

Respondents indicated also other activities – not mentioned in the survey form, which in their case take considerable part of the labor time. "Coordination of the works of research group", which occurs always or almost always and "acquisition of literature" occurring very often shall be included therein.

Table 2. Frequency of activities occurrence in the scientific and research work

		Never	Seldom	Often	Very Often	Always or almost always
1	Analysis of the existing state of knowledge:	17	11	19	8	27
2	Development of the new concept or modification of the existing one:	21	15	22	13	11
3	Planning/preparation of research (laboratory, survey, territorial...):	23	27	22	6	4
4	Conduct of research:	18	23	26	7	8
5	Analysis of the results of conducted researches: (for instance: statistical):	19	22	18	10	13
6	Verification/implementation of the obtained results:	22	39	13	3	5
7	Summary of the works, presentation of the results (for instance preparation of publication):	18	16	15	11	22
8	Correction of publication after review:	20	32	19	4	7
9	Preparation of the review of scientific works:	31	31	9	7	4

Source: Own study on the basis of research results

The fact, that over 60% of respondents regarded the system of scoring of scientific achievements of the Ministry of Science and Higher Education as inadequate to the outlay of work shall be also stressed. Moreover, the respondents stated, that their entities do not possess internal systems of assessment of scientific achievements, regarding simultaneously existence of such system as useful.

In consideration of not numerous sample of the further part of survey form, reliable conclusions on the basis thereof shall not be possible.

4. SUMMARY

Usability of the activities cost account for taking management decisions has already been applied and positively verified, but first of all in the economical entities and certain segments of governmental institutions (the armed forces, health service etc.)

The attempts of application of that method in the public universities are carried out – because changeable market conditions force decision makers of those organizations to effective management, in order to increase their long term value.

However, application of the activities cost account for valuation and calculation of the costs of products of scientific and research process seems to be entirely new ap-

proach. Proposal of the model presented by Authors of the article and partial results of researches in the process of its implementation indicated high usability of information achieved from the model for the requirements of taking management decisions by them.

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COST MANAGEMENT AT A FACULTY
OF A POLISH UNIVERSITY

In the paper a case study of one faculty of a Polish university is presented. Their costing system is analysed and as it turns out to be not useful from the managerial point of view. A suggestion of its modification is formulated. It is shown that the modification, if it is implemented, will deliver useful cost information for the Faculty and for all their present and potential partners: the Ministry of Education, the European Union, the industry partners etc. The whole context of the problem of university costing system is also presented, showing that the proposed direction of changes is necessary, but it is only a beginning of a long and burdensome process towards an efficient university costing system.

1. INTRODUCTION

Universities are now in a period when they are forced to have a completely new look at their costing system. The European Community is strongly encouraging European universities to introduce a full costing system, in which at each university level, for each activity performed at the university and for each customer, product, supplier, organizational unit, process it will be known exactly how much resources it has consumed. European Union is conducting a project called "EUIMA – Full Costing project", whose goal is to make European universities to introduce a full costing system. Estermann (2011) gives several reasons for such a strong insistence on full costing at universities. He says that European universities are now functioning in a more and more challenging environment, in the situating of economic crisis. This means that universities of today have to do "more" with "less". "Less" – because of the economic crisis and the fact that almost 3/4 of universities' funding comes from public funding sources, which are more and more reduced. "More", because universities have to deal

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with a growing competition for talent, resources, excellence, they need to deal and find more various funding sources and also, in order to build up their image, they have to perform various social activities for the society, which was not necessary in the past. As for the funding sources, some universities have more than 100 funding sources (Estermann 2011), more and more of them being private or profit-orientated, and this has been becoming a standard. In order to report to the various donators how their money has been used, universities have to control it, for which they need an adequate costing system. They need it also to be able to get funding, because in the applications for funding hey have to budget their cost in a convincing way.

Espinasse (2011) gives a rather negative picture of the current cost understanding and control at European universities. According to him, the universities generally have little or no understanding of the cost of different activities, of the difference between cost and price and of the fact that on most research grants awarded they lose money. If a complete knowledge and understanding of cost is not present at universities as such, it is even less present among academic staff, out of whom only a small portion have sound economic background. That is why academic staff try to win project funding without worrying about financial consequences. They do not worry about those consequences also because they have no clear system to evaluate them – as they in fact cannot know the cost of the projects they are performing or planning to perform, they can only know the price. Also university managers have often not enough economic knowledge and as a consequence they ask questions like (Fürstenbach 2011): "Why should we pay for resources already there?", referring to e.g. depreciation. They do not understand the notion of cost and the present costing systems of universities do not help them here, as in them the notions of cost, price, cash flow are mixed up and not linked in a clear way to funding sources and products of university activities. In such a general context, knowing that the situation of Polish universities is not much different for those from other countries (Parkitna 2010), we studied one of faculties at a Polish university. The faculty performs teaching tasks, research work, runs research projects and also accepts orders from the industry. It is running several big European projects. It has a dean office and two institutes. The managers of the faculty and of the institutes are professors of engineering. The three units employ research, administrative and technical staff. Our research aimed at answering the following questions:

- Do the managers of the faculty have access to the detailed cost information about the faculty?
- Do they (being engineers and not finance experts) understand it?
- Do they feel they can influence it through their decisions?

If the answer to one of the above questions is negative, is there anybody at the Faculty who can help the managers to make decision, having in mind the costs and their management, as confronted with the effects of the faculty activities?The answer to the above questions has turned out to be overwhelmingly negative. If so, the studied university is still far away from the full costing system – if already at the level of one

faculty, without taking into account indirect cost, thus the cost of support processes at the central level of the university, there no clear, understandable and logical cost information system. What is more, we found also other obviously negative features of the present costing system at the Faculty. We present them briefly in the following and suggest a general direction how the costing system should be improved, so that the cost, at least at the Faculty, become better understood and managed.

2. THE UNIT STUDIED

The unit we studied is one of 12 faculties of a big university of technology. The university altogether has over 40 000 students and employs more than 4000 persons. The structure of the university is as follows: the university, apart from a few extra faculty units (which provide services or customers for the faculties), is divided into 12 faculties, which are, in their turn, divided into institutes, which are further divided into smaller divisions with their own heads. The structure of the university (like that of most Polish universities) has not changed much for many years, even though the political and economic system and the global situation have changed significantly. The university management system is far from being a process management system (Parkitna 2008). It is only lately that it was started to analyze the university management system and to optimize it (Kuchta 2010). It is bound to be a long and burdensome process, but without it the chance for knowing and controlling the full cost are equal to zero.

As the process of university management system optimization has only started, we have not been able to propose a deep analysis and a significant improvement proposal for the whole university. That is why we chose one of the faculties – one of those whose deans expressed the support for any attempt to improve the faculty management.

3. THE PRESENT COSTING SYSTEM AT THE FACULTY

The Faculty has four principal finance sources: teaching subvention from the Ministry of Higher Education, the financing of projects accomplished by the Faculty, including ‚projects financed by the Ministry of Education; projects financed by the European Union; projects financed by other organizations; external orders revenues, the overhead charged to the project accomplished by the Faculty.

The aim of the teaching subvention is to finance the teaching process. Thus, it should cover:
- the depreciation of the equipment and buildings serving for teaching purposes;
- the consumption of materials and energy for teaching purposes;

- the salaries of the employees performing the teaching process, the corresponding social insurance and other benefits;
- services needed for the teaching process, rendered for the university by other organizations;
- taxes and fees (e.g. taxes on property and transportation means used for the teaching process) ;
- other prime costs (e.g. cost of business trips performed for teaching purposes).

The amount of the subvention is a function of the number of students and of a co-efficient, fixed by the Ministry of Education, which should express the cost of educating one student. This coefficient is different for faculties where the use of expensive equipment and material consumption is higher and different where it is lower (the Faculty in question benefits from the highest coefficient possible).

The financing of projects and of external orders should be used for the accomplishment of those projects and orders, a part of it is separated as overhead and should be used to finance the supporting processes.

For each of the three organizational units of the faculty: each of the two institutes and the dean office, there several prime cost accounts. Let N denote the number of prime cost categories (above we listed 6 categories, the list is in reality a bit longer) and M the number of financing sources (the Faculty takes $M = 3$: teaching subvention, all projects and external orders together and the overhead). Then the present costing system can be presented as a matrix $\mathbf{A}(i, j, k)$, where $i = 1, \ldots, L$ stands for the organizational unit (in our case the number of organizational units $L = 3$), $j = 1, ..., N$ for the prime cost category and $k = 1, ..., M$ for the financing source.

For each $i = 1, 2, 3$, all accounts $A(i, j, 1)$ contain the information what has been paid with the money from the teaching subvention. Similarly, all accounts A(i,j,2) show what has been paid by the overhead and the accounts $A(i, j, 3)$ refer to the payments from the different projects and orders. The main problem is that the accounts are source oriented and the information for which purpose the money was used is not easily available. In theory, the money should be used as follows:

- the teaching subvention for teaching purposes;
- the overhead for supporting processes;
- the projects and orders for the very projects and orders.

However, our research has shown that the money is used in a more or less accidental way, according to the principle: "We pay what we have to pay at the very moment with the money we have at our disposal at the very moment". Like Espinasse (2011) said, short term objectives are the main decision criteria at European, and also Polish universities.

And because the system at the Faculty does not show in a clear way for which how much was spent, we have in fact only one information: about the financing sources. But the financing sources are something which we can call the price paid by someone, who expects certain service or products to be delivered and wants the money to be

used for certain activities. Thus the Ministry pays for the teaching and should not (at least in theory, because the way of thinking at the ministries of education is not adequate either (Espinasse 2011)) allow their money to be spend e.g. on European projects, for which someone else paid, or on administration processes, which should be financed by the overhead. But such things are done almost every day, which has been shown by our research.

Like Espinasse (2011) shown in his research, we found out that at the Faculty there is no clear understanding of the difference between price, cost, resources and products. Fig. 1 shows a lack of equilibrium and even a lack of any clear relationships between the price (financing sources), the use of resources (cost) which takes place while performing activities and the effects, the products the price is destined for.

Table 1. The relations between financing sources, university resource consumption and effects

Financing sources	Activities/resources used	Effects
Teaching subvention	Teaching activities	Quality of teaching
Overhead	Support activities • for teaching • for projects • for administration	Quality of support activities
Projects and orders	Research activities	
		Quality of project products

In theory in the above table we should have only horizontal division lines going throughout the whole table, from the left to the right hand side. But it is not like this. In some periods the teaching subvention is used for almost everything, in other periods the overhead is used for teaching processes (this is the situation depicted in Table 1). In other cases the money from projects is used for teaching activities. What is a common phenomenon is that if something or someone was paid from one money source in one year (e.g. from a project) and this was even more or less correct (thus corresponded to the momentary use of the resource), but then the person or the piece of equipment started to be partially or totally used for other kind of activities, the payment for this resource continue "forever" to be recorded in the same, original account.

A problem is also another common phenomenon, which is the use of a resource for different activities. E.g. a piece of equipment (above all computers) or software, financed from one source, is very often used for realizing the teaching, the organizational, the commercial and the research activities. However, its depreciation is recorded always in one account, corresponding to the one financing source. Also, all the

salaries of the teaching staff (except of the part paid out of projects) are paid completely from the teaching subvention and recorded at the accounts $A(i, j, 1)$, which does not show the real cost of teaching: the time, which is the main resource offered by the academic staff, in reality is used only partially for teaching, it is used for all the other kinds of activities also. Apart from that, the Faculty in question rents several expensive services, surfaces and equipment and uses them for various activities, although they are recorded with connection to only the one financing source used to pay the rent.

The above mentioned depreciation constitutes a problem per se. The Faculty is imposed certain deprecation amounts to be paid by the central university administration, but the Faculty finance experts do not have any information how the depreciation is calculated. There are no official documents at the central level clarifying the deprecation calculation system – it seems to be a "secret knowledge", reserved to a restricted circle of finance experts at the central university level.

We can take as granted that the depreciation is calculated not with the aim to support the management of university assets, but with the mere aim to comply with some regulations. Thus, the Faculty cannot use depreciation information for management purposes: they do not know how it s calculated and thus they cannot use it as a measure of the actual usage of the assets. If so, they are unable to estimate the true cost of almost any activity performed: most activities do use more or less expensive assets, but if the depreciation is calculated in a "secret" way and what is more, is (what we mentioned above) always linked just to one financing source, it is absolutely impossible to find out the cost of education of a student, of performing a project etc. Let us emphasize again we are talking about cost, not price – i.e. we are talking about the information how much resources are used for a student, a project etc. That is why, e.g.:

- the academic staff may apply for projects on which the Faculty (and the University) loses money, but as nobody knows it, they are motivated to go on (a confirmation of Espinasse (2011) findings);
- if nobody can say how much costs the education of different categories of students, the Faculty in question may benefit from the highest possible teaching subvention coefficient. The Ministry has to means to control it, and the money from the teaching subvention can be used for many non-teaching activities. At the same, another faculty of the same university has been assigned by the Ministry a considerably smaller teaching coefficient, which they find completely unjust – as in their opinion the difference in teaching cost between the two faculties is by far not that high. But they have no means to prove it and have to use other financial sources to finance the teaching activities.

Also, in the present costing system at the Faculty there is no evaluation of the products the organizations paying the prices (the different financing sources) get. In fact, as far as the teaching subvention is concerned, we do to really have a clear defi-

nition of the product, of the quality of teaching expected by the Ministry. So, the Ministry pays for something which is not defined, it pays a price calculated on the basic of a coefficient which should reflect the teaching cots, but it obviously does not, as those costs are not known...

Altogether, we have found out that the present costing system used at the Faculty does not help managers to make decisions. It is strongly financing source oriented and it seems that its primary aim is to "make everything look OK for the moment". It serves to make decision only with respect short term goals.

4. A PROPOSAL OF CHANGES IN THE COSTING SYSTEM AT THE FACULTY

We do not claim here to be able to solve all the problems mentioned in section 3. Those problems can be solved only of the whole university changes the system in cooperation with the Ministry. The process has begun, but the university has still a long way ahead. However, we think that some changes can be introduced on the Faculty level and they will help to manage the cost and understand it at least to a certain degree. And they will prepare the field for the great battle – that of introducing the full cost concept at the whole university.

We propose first of all to change the dimensions of the matrix $\mathbf{A}(i, j, k)$. It should be replaced by a matrix $\mathbf{A}(i, j, k, l)$, where $i = 1, ..., L$ will stand for the organizational unit (in our case the number of organizational units $L = 3$), $j = 1, ..., N$ for the prime cost category, $k = 1, ..., M$ for the financing source and $l = 1, ..., P$ for the number of identified activities.

As far as M is concerned, in the studied case $M = 3$, but we propose to differentiate much more financing sources. There should be at least as many of them as numerous are the various organization who provide money to the faculty. This will assure that each organization paying a price will be able to see what its money went for. The additional matrix dimension, that of activities ($l = 1, ..., P$), should introduce into the present accounting system the notion of the goal for which resources (paid by someone) are used. Of course, the goals may be defined in various ways, but, according to the most popular full costing method, the Activity Based Costing, the resources are used by activities and we propose to apply this approach here. The question how detailed the list of activities should be is open, but we should at least consider the following categories:

- teaching activities,
- organizational activities,
- research activities,
- external order related activities.

Within each category we should identify subactivities (some proposals of how to do this for teaching and research activities can be found in (Klaus-Rosińska and Kowalski 2010) and (Kowalski and Klaus-Rosińska 2010), but the first step should be to consider at least the above four categories, thus to take $P = 4$.

Then each recording of a prime cost position in the accounts should be preceded by answering the following questions (we assume the values of i and j is determined in an obvious way, although even here a deeper reflection would be needed in the future, as to the prime cost categories used):

- where does the money come from ($k = 1, ..., M$)
- which activities used this prime cost in the period of consideration (here we very often will have to choose not just one element, but a set of several $l = 1, ..., P$) and in which proportion.

The question about proportions is not easy to answer. Here various tools can be used, like staff surveys, staff interviews, profile creation for individuals performing similar tasks, time sheets etc. (Österber-Dobson 2011). Our observation is that the interviews method may be quite sufficient to start with. In this way we have found out, in an approximated form of course, the proportion of time used by academic and administrational staff of the Faculty for various activities. Other documents (lectures schedules, work sheets etc.), allow to distribute the use of equipment and surface between various activities.

Of course, this approach will not be easy to be implemented, because it changes the way of thinking of the financial staff at the faculty. Also, if the various categories (the four dimensions of the matrix) are not numerous enough and/or if the distribution of the use of resource between activities is not exact, the information got would not be perfect either. However, it will already give a more useful information that the present system does, e.g.:

- if we sum up all the $A(i, j, k, l)$ for a fixed $k = 1, ..., M$, we will get all the financing we got from the k-th source;
- if we sum up all the $A(i, j, k, l)$ for a fixed $k = 1, ..., M$ and a fixed $l = 1, ..., P$, we will see how much money coming from the k-th source has been used for the l-th activity;
- if we sum up all the $A(i, j, k, l)$ for a fixed $l = 1, ..., P$, we will see how much the given activity has cost;
- etc.

If this information is linked to a quality measuring system (some proposals for such a system can be found in (Ryńca and Klaus-Rosińska 2010)), then we (and everybody interested) would be able to see the relationship between the price, the cost and the product. And it seems that without this information no efficient university management is possible.

5. CONCLUSIONS

In the present paper we proposed a small step towards an efficient costing system for universities: a multi-dimensional cost recording system, based on the critics of the existing systems at the Faculty of one of Polish universities. If our proposal is implemented, the Faculty and its partners will have at their disposal a much more useful cost information than they have today.

Even once our proposal is implemented, this will be only the beginning of a hard road towards a good (from the managerial point of view) costing system. The experience of those universities which have succeeded in implement a full costing system show clearly that it s a very difficult process, both from the technical point of view (it requires expertise and above all time – at a Finnish university two persons had to work full time for one year on the issue (Österber-Dobson 2011)) and from the human point of view. Our research showed clearly that most of the academic staff (the management of the university included) are not quite persuaded as to the need of all these deep changes and they saw our data and information collecting activities as innocent, but purely theoretical activities, which were time consuming, but rather useless to them. We hope that our experiment at the selected Faculty will contribute a bit to the mentality change, which is absolutely necessary for an efficient costing system to exist and work. As Espinasse (2011) says: Full costing is a tool, not the solution". We hope our research fits this scheme.

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THE CONCEPT OF AN ENVIRONMENT
FOR SERVICE MODEL APPLICATION TESTING

Modern computer science comprises both a service and its management [9]. It is hard to imagine that the software which is currently produced and has been accepted by the client was not based on a service-based architecture. Therefore, the subject of making such an application is important from both the standpoint of organization support (producing information systems based on services) as well as the client's organization (which receives the produced services). Although relatively much is said about the production of applications based on Service Oriented Architecture (SOA)[5,6,10], little is said about the technologies that support the production of such applications. Should they also have the structure of a service and provide only a single service, or constitute fundamental applications?

The authors have assumed that both applications for the client as well as information technologies supporting the production process of applications should be based on services. This approach results from the simple fact that both modern manufacturing techniques and client applications should be based on similar architecture. In this case, experiences gained during the manufacturing process are transferred to the knowledge used to build service-based client applications. Therefore, this paper presents the concept of an environment for the production (testing) of service-based applications. The authors have adopted a solution within the frame of which the completed manufacturing process of applications designed for the recruitment of students, along with the IBM's Quality Manager platform and the IT infrastructure constructed for the needs of this application can provide a common research environment for service application testing. At the beginning, for the presentation of this concept, technologies that support the software testing process have been presented. Then the application for the recruitment of students and the possibility of its construction based on SOA architecture has been discussed and the solution has been evaluated. Similarly,this has been done with IT infrastructure. Knowledge collected in this way about three independent, but coherent (from the perspective of research) environments, allows the concept of a service environment for application testing (USTA) to be developed.

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1. INTRODUCTION

Their roles and tasks, provide a work plan and allow the testing of the product before deployment. Customer requirements are the determinant for the selection of technology to the needs of the application. This prompts the question of whether it is possible to use only one generic technology for testing any projects.

It seems that The development of information technology contributes to the growing demand for high-quality software. Despite the strong base of well-educated programmers and analysts, as well as the constantly developing infrastructure, there are applications that do not meet the customer's requirements. There is still the search for a reliable, fast and easy way of software development. Programming experience shows that there is a clear correlation between quality assurance processes and the resulting quality of software through these processes. This approach forces the identification of new technologies and their functionalities for the full cycle of software production [20].

Testing processes play a particular role in the software production process. They significantly determine the performance and construction quality of produced applications. Large IT companies support the software testing process with the Lower Case type of technologies. The performance of these technologies largely depends on the knowledge of code as well as on the degree of matching the technology to the specific application language and code. Therefore, more and more questions arise about how to effectively support software testing processes. From the viewpoint of the provider's organization, which produces and tests the produced applications, to respond to this is crucial.

Creating design specifications, stacking requirements, and implementing the application code are all provided by available technologies. These technologies also provide communication between the project team members, support the team members in the course of advanced technologies often have a number of features that in many cases are not needed. However, the use of basic elements of these technologies requires the knowledge and configuration of more advanced elements [7,12]. In result, it takes time to become familiar with all aspects of the assistive technology production process and in many cases it is insufficient. Time is a significant factor for small projects, so teams often tend to use several smaller solutions, which causes problems with integration. Simple technologies often do not have interfaces for exchange between components. Therefore, the application building process is complicated. In addition, sometimes simple projects require considerable expansion.

In fact, it requires the refactoring of available code and modification of functionality. The process of searching for more advanced technology to support the production (testing) of applications has to be started. In such a situation, changing to more advanced technology as a whole is difficult to accept. Undoubtedly, the best solution would be to use advanced technology which provides only some of the functionality and, if necessary, to enable any further functionality.

2. IT TESTING TECHNOLOGY

We start by analysing technologies used to support the testing process, from the evaluation of simple technologies such as: SVN, TRAC, PHPUNIT, ECLIPSE. TRAC is an application for project management, tracking bugs and defects with open access to source code [22]. The application is available via a web browser, thus is available to multiple users without installing additional software. It is important that TRAC has an interface to synchronize with version control systems such as: Subversion, Git, Mercurial, Bazaar, Perforce and Darcs. TRAC allows information to be synchronized between the base errors, version control and content of the knowledge base. It is used as a ticket system (bug tracking, tasks). It allows the defining of different levels of user access, viewing recent activity timelines, customizing and generating reports, running RSS feeds. Many projects and repositories are supported by this technology. This technology greatly helps with the production of applications in conjunction with the version control system. The version control system allows all changes which were made to a project's files to be saved. The user is able to recover the selected version of a file or an entire project at any time. TRAC also provides the opportunity for many programmers to work with one code version. It also provides transparent control changes in the code and displays the modified code fragments earlier.

The IBM Rational – Rational Quality Management (RQM) – is a more advanced application testing product. It provides integration and information flow between users working around the world. The software life-cycle tracking process on programming and production is one of the main functionalities of RQM. Moreover, these technologies provide the modernization of the existing code. RQM provides information security standards compliant with Web site security and can be used by small and medium-sized enterprises through the use of modules. It works with most popular operating systems and RQM installation is relatively simple, through the use of an interactive installer. RQM provides three main products: Requirement Manager, Quality Manager and Configuration and Change Manager.

For the purpose of this paper the Rational Quality Manager was tested and the overall Quality Requirement was assessed, to build the concept of USTA. A typical process using the Rational Quality Manager is based on managing tests, creating and running test scripts, and managing and reporting defects. The RQM is divided into a variety of user's roles occurring in the software development process. The possibility to define requirements, test plans, instructions and create status reports was found in the RQM during the research. The possibility to create testing scripts and execute instructions, saving all the irregularities and comments, was also discovered.

RQM users can create their own view in the RQM application. The user by using the control panel can arrange the view, so that the foreground can be the most important elements of the project or task. The project's status, team or load can be reviewed. The au-

tomation of testing functionality can be important and useful. The RQM executes instructions faster corresponding to user movements in the applications, which was shown in tests on the IRK example. The RQM also allows the automation of testing instructions by use of other Rational products (Functional Tester, Performance Tester, Service Tester for SOA Quality, Robot, AppScan Tester Edition). However, the lack of a simple interface for testing applications such as Web applications, which could be used to simulate a normal user's operation during testing, was found.

3. APPLICATION FOR REGISTERING STUDENTS

To present the service environment for application testing – USTA, it becomes necessary to show the application which is the subject of the research a system of recruiting candidates for studies, which will be developed and tested with technology to test it. First, the Online Candidates Registration System (IRK) structure was shown.

The IRK is a specific product. It combines many aspects of various types of web applications. A few or sometimes even several thousand new users per year use it. Several specific requirements are expected from this kind of application. The application should guarantee the security of stored data, be intuitive, not cause problems in use and be reliable for the many users served. Moreover, it should be possible to customize it for individual customer needs. In result, we receive a product which is technologically advanced. Design experiences and advanced software for the suitable preparation of specifications and requirements to write and test applications are required.

The typical process, working on the IRK application, is as follows. The user reports an error in the program or the need for a new functionality via e-mail, a newsgroup or the TRAC system interface. The notification is archived in the TRAC. The identifier, category, priority, etc. are assigned to the notification. The submitted postulate is identified by the coordinator of the project. Subsequently, the postulate is approved or rejected by the coordinator with adequate justification. If the postulate is accepted and does not require any further clarification or requirements, the preliminary documentation is created. After that the postulate is assigned to the appropriate developer. At the same time the status is updated, the priority is fixed and the execution time as well as the cost of work is estimated. If the postulate is unclear or vague it is discussed for relevant information. The relevant work is done by the programmer in the application code. Each change is tested by unit testing and the individual programmer's testing. Unfortunately, it is not possible to verify all tests performed by the programmer. After changes are made, the programmer completes the documentation of the changes (if any are required), synchronizes with the trunk, eliminates other programmers' conflicts and approves the changes to the repository by assigning an appropriate com-

ment. Then the approval number is written by the programmer in the ticket. The project coordinator briefly checks the changes, and then combining them with the main version of the IRK system, automatically runs scripts and application tests. The team of testers starts work. Testers perform acceptance tests. If everything works according to the requirements, the changes are linked to the production branch (trunk). After an installation file is generated a new version of the application is made available for customers. If there are any mistakes or tester's remarks, they shall be reported to the project coordinator. The project coordinator draws up a note of the received report and places the information in the TRAC system. In addition, the file is generated with summary changes in the code. Then the responsible programmer receives the information. The developer makes the necessary corrections and proceeds in accordance with the earlier process.

For the example of the integration of IRK with the ePUAP platform, a typical workflow can be defined as follows. The project coordinator creates a test plan by using RQM technology. The plan must be drawn up on the basis of one of the available templates. It is possible to create a custom template. Checking the correct operation of Web services technology in the IRK product is one of the examples of such a test. For the next step the data flow between the two platforms might be tested. The test plan with testing instructions, which is assigned to testers, is combined by the project coordinator. Testers create testing scripts using the defined requirements and combine them into instructions. The testing scripts are approved by the project coordinator.

In the next step the testing environment, which can be created using the RQM product's functionality, is created and is called the laboratory. Management of the laboratory allows appropriate platforms and applications for testing to be defined. There is no such element in simple solutions. Elements like operating systems, browsers, sources of data exchange, database systems and the like are not simple solutions. The RQM's laboratory package allows data to be created for physical machines and virtual images, and allows the search for specific configurations of resources and management demands. It is possible to update data on laboratory resources, in the case of integration with applications vendors to enable the implementation and enumeration of resources [23, 24].

4. IT INFRASTRUCTURE OF THE PROPOSED ENVIRONMENT

The IT infrastructure is based on two areas. The first of them contains the IRK system. It contains the web server with database storage. The whole architecture is based on VMware engine [21]. It offers great opportunities for testing. The biggest advantage is the ability to dynamically define and change the hardware parameters. The IRK system runs on a virtual server. For example, if in a certain period of time the number

of users are lower than expected, the administrator can decrease the amount of disk storage or system memory [18]. Then there are more resources for other units or systems. On the other hand, we can increase the speed and number of processors during the activity of many users or when running tests which require large computing resources. Moreover, we can add as many network interfaces as we like, e.g. when adding access for a tester by virtual private network (VPN). This kind of solution is very flexible and allows the application to be tested in different kinds of situations. We can simulate the application's behaviour based on the environment defined in the RQM's laboratory. VMware is a free tool. VMware typically works under the Linux system. The web server and other operating systems installed under VMware are standard [17, 19].

The web server runs under Debian Linux distribution using the Apache 2 package. It requires 1GB of RAM, 2x2.0GHz processor. The IRK system also requires the MySQL database. The capacity of the database is different and depends on registered users. The server has extra storage for database backup, but it is not required for testing. A few programs must be installed on the server. Additional programs are described in detail in the installation guide for the IRK system.

The second area contains the RQM application. The RQM is installed on the Windows Server 2008 operating system with a public network interface. The requirements for RQM are much higher. The server has 4 GB of RAM memory and 2x2.0GHz processor with a 40GB storage disk. This configuration allows 10 users to work comfortably with the browser. The RQM works on the Jazz Team Server with the Apache Tomcat 5 web server.

For the research we have a dedicated laboratory which contains six workstations. Windows 7 is installed on each workstation as the operating system. Each workstation has a stable network connection to the RQM and IRK server and web browser. The users can access the servers via a secure connection (SSL). Such a solution enables users to work from any kind of workstation in the world with an Internet connection.

5. SERVICE ENVIRONMENT CONCEPT
FOR APPLICATION TESTING

The concept of the USTA environment is based on knowledge from presented technologies. This concept assumes that the structure of the environment (figure 1) contains three elements: IT infrastructure, service-based application testing technology and the IRK application [15,16]. It has become necessary to analyze processes that demonstrate how consistent the proposed approach is. Therefore, the consistency of processes which were used in testing the classical IRK application were used for the analysis. It was also assumed that the RQM would be used in place of simple technol-

ogies and will be developed for SOA architecture. It is assumed that the automatic application testing scripts will be based on libraries (Codegen PEAR package was used in this study of the IRK application, which allows scripts to be created that simulate user interactions). It is also assumed that the testing of individual modules/functionalities are created by using XML [13,14].
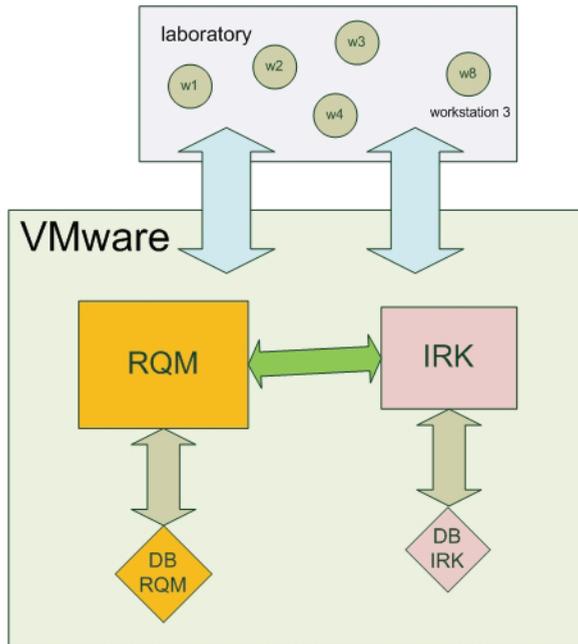
Fig. 1. The structure of the USTA environment

It is assumed that the program must be installed separately and a configuration file must be created to run the scripts. The configuration file should contain the information needed to connect to the database and log into the system. The structure of the test file should contain instructions for sequentially performed operations on the application. The user should have the possibility to transfer test parameters. Test instructions should search for the result in the stream returned by the application. Each statement should return the result of testing. In this case, the testing instructions are made by the programmer on the piece of code which has been created. Therefore, there is no control over the quality and correctness of testing. Therefore, a set of multiple files are created, each with a number of testing instructions, which leads to the entire application package. Results of such tests are visible to developers and the project coordinator. The correctness of the software is manually tested by the user. The integration process of the IRK system and e-PUAP system is an example of such a solution.

In this case, the mechanisms for SSO (Single-Sign On) should be created for both the technology as well as the applications site. Figure 2 shows an example of the testing process based on the USTA.
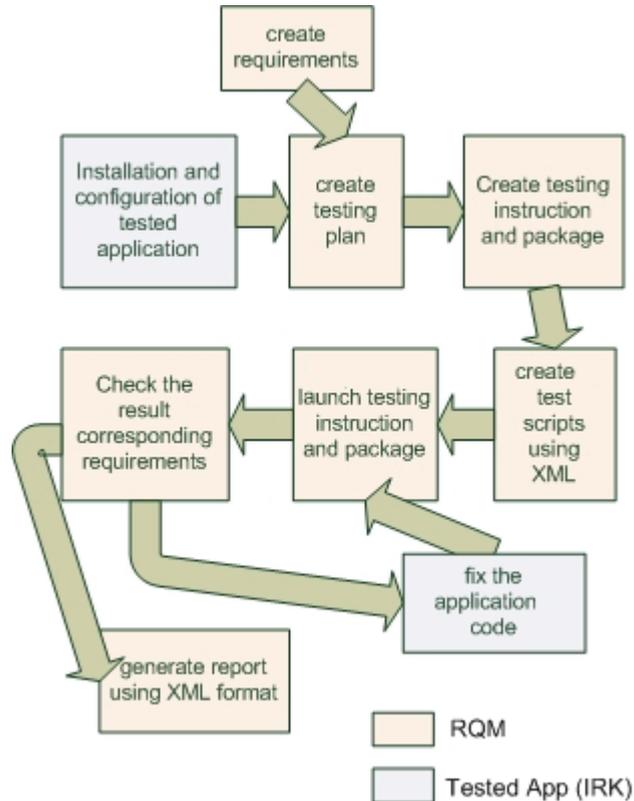
Fig. 2. Example of the testing process based on USTA

6. CONCLUSIONS

This paper presents the concepts of a service-based application testing environment (USTA). At the beginning the technologies used in the process of application testing were discussed. In the next step the IRK application for the recruitment process was presented, which is an example of a closed application. This application can be opened for research from the viewpoint of carrying out tests on the internal IT infrastructure. A description of this infrastructure has also been presented in this paper. The purpose of these three descriptions was to show three different elements which can serve as

a common environment for application testing. The concept of the USTA environment is shown in Chapter 4.

The following comments and observations, the objective of which is the concept of a service-based application testing environment, have appeared during research.

1. The concept of building an environment for service-based application testing becomes necessary to diagnose potential technologies as well as the IRK application (proposed in this paper – RQM).

2. The multifunctional IRK application presented in this paper may be treated as an application of research for developing a generic model of a test environment (due to the knowledge of the application's functionality).

3. The knowledge of simple technology for testing the application presented in this paper becomes a big advantage for the construction of the environment as well as the opportunities to translate their functionality to the complex RQM environment.

4. The elaboration of the generic RQM model might be crucial for building a model for a service-based application testing environment. However, this can only occur if attempts are made to integrate well-known environments, and other existing ones described in the literature, but most of all, through an analysis of RQM.

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PART 3

MANAGEMENT OF FINANCIAL INFORMATION
IN BUSINESS ORGANIZATIONS

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COMPARATIVE ANALYSIS OF THE BANKRUPTCY PREDICTION MODELS

During rapid changes in the financial market, it is rather important factor to determine the ability of enterprises to continue operations, therefore different bankruptcy prediction models are used. This article will investigate 34 corporate bankruptcy prediction models such as Beaver model, Altman's model and in particular Polish models including models of: Mączyńska, Prusak, Hadasik etc. Aim of this study is to conduct a comparative analysis of selected models in terms of predicting bankruptcy of enterprises. To achieve this aim, we used financial data of 100 companies that declared bankruptcy in the years 2005 – 2010. This research also aimed at selecting the most versatile models and identifying common features in their construction, which embody predicting capabilities. Additionally, we have looked into bankrupt companies that were classified as solvent by examined models.

1. INTRODUCTION

This article investigates bankruptcy prediction models, models of early warning against the dangers for continuation of economic activity, by assessing their effectiveness in predicting bankruptcy of enterprises. The most common group of models for bankruptcy prediction are models of discriminant analysis [1]. In essence, such models separate a set of data for two or more groups, and this separation produce essential information for subject applying the model.

Discriminant analysis uses ratio analysis and formal reasoning tools. Synthetic index is constructed based on empirical data, which usually consist of several sub-indices, which are assigned as so-called weight. Discriminant analysis thus seeks to reduce the multidimensional space of the number of variables to a single aggregated size [8,11]. Bankruptcy

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prediction models are built with different indicators and therefore it is vital to select only indicators that are informative, which means have predictive capabilities.

This study examines 34 models of discrimination. Assessment of their effectiveness was done by analyzing sample data of 100 companies operating in Poland, which had declared bankruptcy in the period between 2005 and 2010. This study allowed to assess the level of predictive capabilities of models under consideration and the selection of indicators of high informative value.

2. MODELS OF DISCRIMINANT ANALYSYS

Studies evaluating the level of predictability of chosen models were conducted on the basis of company's financial data, which declared bankruptcy and operated in Poland. The specification of a given country, sector or size has a significant impact in the assessment of the company. However, the study was not limited solely on the polish models. The study used the following 34 models of discriminant analysis:

1. Prusak 2
2. Prusak 4
3. Appenzeller i Szarzec 1
4. Gajdek and Stos 3
5. Gajdek and Stos 2
6. Legault
7. Prusak 1
8. Springate
9. Prusak 3
10. Mączyńska
11. INE PAN7
12. INE PAN6
13. Gajdek and Stos 4
14. Wierzba
15. Hadasik 2
16. Appenzeller and Szarzec 2
17. Altman
18. Beaver
19. Quick Test
20. Hadasik 3
21. Hadasik 5
22. Hadasik 4
23. Hadasik 1
24. Hamrol, Czajka and Piechocki
25. Janek and Żuchowski
26. INE PAN5
27. Taffler
28. Hałdy
29. INE PAN1
30. INE PAN2

31. INE PAN4
32. INE PAN3
33. Pogodzińska and Sojak
34. Gajdek and Stos 1

Detailed description of all models can be found in [3, 4, 5, 6, 7, 9]. In the next part of this material, we only present models that showed the best ability to classify bankrupt companies.

3. COMPARATIVE ANALYSIS OF PREDICTIBILITY
IN DISCRIMINANT MODELS

Examination of each model was conducted based on the financial statements of the undertakings, while analyzing the predictive ability for the year, two and three years before bankruptcy. If the model correctly predicted the bankruptcy of the enterprise, it received one point, otherwise no point for the model was granted. After evaluating each of the 34 models of the 100 studied companies, we totaled the number of points awarded, separately for the year, two and three years before the bankruptcy, which allowed comparison of their effectiveness. The values obtained allowed us to determine by percent the level of predictability.

The aggregate results of the study are presented in Table 1, where the higher the percentage allocated for a given model, the less companies have been designated as insolvent, that is, the higher the level of bankruptcy prediction. The most effective models were: Prusak 2, Prusak 4, Appenzeller i Szarzec and Gajdek and Stos 3.

Table 1. The percentage stores detecting insolvency for each year

No.	Name	3 years	2 years	1 year	Average
1	Prusak 2	87%	78%	89%	85%
2	Prusak 4	87%	77%	89%	84%
3	Appenzeller i Szarzec 1	79%	76%	91%	82%
4	Gajdek and Stos 3	82%	76%	86%	81%
5	Gajdek and Stos 2	72%	70%	83%	75%
6	Legault	67%	65%	87%	73%
7	Prusak 1	69%	68%	78%	72%
8	Springate	66%	61%	81%	69%
9	Prusak 3	64%	65%	76%	68%
10	Mączyńska	37%	67%	67%	57%
11	INE PAN7	43%	44%	75%	54%
12	INE PAN6	40%	45%	73%	53%

13	Gajdek and Stos 4	49%	44%	64%	52%
14	Wierzba	43%	45%	69%	52%
15	Hadasik 2	41%	45%	69%	52%
16	Appenzeller i Szarzec 2	36%	38%	67%	47%
17	Altman	34%	39%	67%	47%
18	Beaver	32%	33%	68%	44%
19	Quick Test	33%	32%	61%	42%
20	Hadasik 3	32%	27%	48%	36%
21	Hadasik 5	29%	31%	46%	35%
22	Hadasik 4	26%	27%	51%	35%
23	Hadasik 1	26%	29%	42%	32%
24	Hamrol, Czajka i Piechocki	29%	26%	41%	32%
25	Janka and Żuchowski	27%	24%	42%	31%
26	INE PAN5	25%	21%	46%	31%
27	Taffler	35%	17%	29%	27%
28	Hałda	21%	16%	44%	27%
29	INE PAN1	17%	15%	36%	23%
30	INE PAN2	13%	12%	29%	18%
31	INE PAN4	13%	12%	27%	17%
32	INE PAN3	12%	10%	24%	15%
33	Pogodzińska and Sojak	9%	11%	21%	14%
34	Gajdek and Stos 1	6%	11%	3%	7%

Source: Own work.

Table 2 shows the relationship between results of solvency in different years for the model. The correlation for the models: Altman, Legault, Springate, Prusak 3, Hołda, Appenzeller andSzarzec 1, Hadasik 1, Hadasik 3, Hadasik 4 for trials conducted at two and three years and for one and two years before bankruptcy Mączyński model is high. For other models and years, the correlation is low or the results are statistically insignificant. Taking into account the fact that the study was conducted on the same companies by similarly designed models, these results are surprising. Low correlation means that the same model, when examining a constant attempt, showed completely different companies, as being at risk of bankruptcy in different years.

Table 2. The correlation for the models depending on the time of studied business.
Developed by SPSS (grey colour – insignificant results)

Mo-del(year)	ALT1	ALT2	ALT3		PAN61	PAN62	PAN63		HOL1	HOL2	HOL3
ALT1	1	,343	,234	PAN61	1	,188	,129	HOL1	1	,328	,137
ALT2	,343	1	**,681**	PAN62	,188	1	,410	HOL2	,328	1	**,579**
ALT3	,234	**,681**	1	PAN63	,129	,410	1	HOL3	,137	**,579**	1
	BEAV1	BEAV2	BEAV3		PAN71	PAN72	PAN73		HCP1	HCP2	HCP3
BEAV1	1	,162	,057	PAN71	1	,047	-,012	HCP1	1	,155	,184
BEAV2	,162	1	,339	PAN72	,047	1	,410	HCP2	,155	1	,425
BEAV3	,057	,339	1	PAN73	-,012	,410	1	HCP3	,184	,425	1
	LEG1	LEG2	LEG3		JIZ1	JIZ2	JIZ3		AIS11	AIS12	AIS13
LEG1	1	,340	-,018	JIZ1	1	,281	,076	AIS11	1	,314	,095
LEG2	,340	1	**,511**	JIZ2	,281	1	,397	AIS12	,314	1	**,630**
LEG3	-,018	**,511**	1	JIZ3	,076	,397	1	AIS13	,095	**,630**	1
	SPR1	SPR2	SPR3		PIS1	PIS2	PIS3		AIS21	AIS22	AIS23
SPR1	1	,449	,190	PIS1	1	,211	,009	AIS21	1	,111	-,005
SPR2	,449	1	**,638**	PIS2	,211	1	,224	AIS22	,111	1	,486
SPR3	,190	**,638**	1	PIS3	,009	,224	1	AIS23	-,005	,486	1
	TAF1	TAF2	TAF3		GIS11	GIS12	GIS13		HAD11	HAD12	HAD13
TAF1	1	,297	,085	GIS11	1	,313	,202	HAD11	1	,305	,188
TAF2	,297	1	,282	GIS12	,313	1	,449	HAD12	,305	1	**,526**
TAF3	,085	,282	1	GIS13	,202	,449	1	HAD13	,188	**,526**	1
	ST1	ST2	ST3		GIS21	GIS22	GIS23		HAD21	HAD22	HAD23
ST1	1	,082	,065	GIS21	1	,343	,251	HAD21	1	,259	,119
ST2	,082	1	,339	GIS22	,343	1	,467	HAD22	,259	1	,472
ST3	,065	,339	1	GIS23	,251	,467	1	HAD23	,119	,472	1
	MAC1	MAC2	MAC3		GIS31	GIS32	GIS33		HAD31	HAD32	HAD33
MAC1	1	**1,000**	,097	GIS31	1	,313	,111	HAD31	1	,362	,156
MAC2	**1,000**	1	,097	GIS32	,313	1	,285	HAD32	,362	1	**,597**
MAC3	,097	,097	1	GIS33	,111	,285	1	HAD33	,156	**,597**	1
	PAN11	PAN12	PAN13		GIS41	GIS42	GIS43		HAD41	HAD42	HAD43
PAN11	1	,210	,049	GIS41	1	,203	-,098	HAD41	1	,272	,201
PAN12	,210	1	,332	GIS42	,203	1	,380	HAD42	,272	1	**,564**
PAN13	,049	,332	1	GIS43	-,098	,380	1	HAD43	,201	**,564**	1
	PAN21	PAN22	PAN23		PRU11	PRU12	PRU13		HAD51	HAD52	HAD53
PAN21	1	,171	-,050	PRU11	1	,257	,062	HAD51	1	,423	,162
PAN22	,171	1	,406	PRU12	,257	1	,467	HAD52	,423	1	,429
PAN23	-,050	,406	1	PRU13	,062	,467	1	HAD53	,162	,429	1
	PAN31	PAN32	PAN33		PRU21	PRU22	PRU23		WIE1	WIE2	WIE3
PAN31	1	,203	,081	PRU21	1	,276	,054	WIE1	1	,215	,102
PAN32	,203	1	,492	PRU22	,276	1	,441	WIE2	,215	1	,392
PAN33	,081	,492	1	PRU23	,054	,441	1	WIE3	,102	,392	1
	PAN41	PAN42	PAN43		PRU31	PRU32	PRU33				
PAN41	1	,122	-,034	PRU31	1	,226	,164				
PAN42	,122	1	,406	PRU32	,226	1	**,542**				
PAN43	-,034	,406	1	PRU33	,164	**,542**	1				
	PAN51	PAN52	PAN53		PRU41	PRU42	PRU43				
PAN51	1	,214	,023	PRU41	1	,264	,339				
PAN52	,214	1	,383	PRU42	,264	1	,495				
PAN53	,023	,383	1	PRU43	,339	,495	1				

Source: Own work.

The selection also included companies, that were cited least often as bankrupt by all models, which was presented in Table 3, which takes into account the period prior to bankruptcy.

Table 3. The percentage of detection of bankruptcy for each company by all models in all years

No.	Company	1 year	2 years	3 years	Total period
1	ALUMAST S.A.	3%	0%	3%	2%
2	LAFARGE CEMENT S	3%	3%	3%	3%
3	Systemics Poland	9%	3%	21%	11%
4	Conbelts Bytom S	21%	3%	15%	13%
5	BAUSTAL s.j.	9%	21%	18%	16%
6	Przedsiebiorstwo	3%	3%	44%	17%
7	Ares Sp. z o.o.	12%	26%	15%	18%
8	Progres Sp. z o.	21%	12%	24%	19%
9	FormaPlan Sp. z	38%	9%	15%	21%
10	TK TRADE Sp. z o	41%	12%	15%	23%
11	ZNTK lapy S.A.	9%	3%	62%	25%
12	Naft Stal Sp. z	53%	18%	6%	25%
13	ADRIANA S.A.	24%	29%	26%	26%
14	DUDA-BIS Sp. z o	21%	32%	29%	27%
15	PIECBUD BYTOM S.	50%	3%	35%	29%
16	KUzNIA POLSKA S.	79%	6%	3%	29%
17	HUTA CYNKU Miast	26%	62%	3%	30%
18	TECHNIC INDUSTRY	76%	12%	3%	30%
19	Poltarex Sp. z o	82%	6%	3%	30%
20	SM Nowa Jastrzeb	18%	62%	15%	31%
21	Bystrzyckie Fabr	79%	9%	6%	31%
22	PHS luzyce Sp. z	56%	26%	15%	32%
23	POLDIM-MOSTY Sp.	6%	15%	76%	32%
24	PBP Orbis Sp. z	29%	29%	41%	33%
25	ESO Sp. z o.o.	91%	6%	3%	33%
26	DOMAR Bydgoszcz	29%	38%	35%	34%
27	MONNARI TRADE S.	94%	6%	3%	34%
28	CALITAN Sp. z o.	85%	6%	12%	34%
29	MAZUR COMFORT Sp	74%	15%	15%	34%
30	LOTOS JASlO S.A.	29%	32%	41%	34%

Source: Own work.

The analysis of correlation between the models and results for individual years shows that, application of the following models: Prusak 2, Gajdek and Stos 2, Gajdek

and Stos 3, Gajdek and Stos 4 for three years before bankruptcy allows to indicate all companies as bankrupt. The following six models should be applied two years before bankruptcy: Prusak 2, Gajdek and Stos 1, Gajdek and Stos 2, Gajdek and Stos 4, Mączyńska 2, Appenzeller and Szarzec 1, and one year before bankruptcy: Prusak 2, Gajdek and Stos 2, Appenzeller and Szarzec 1. At the same time it should be noted that two years before bankruptcy one company: Alumast SA, was not indicated by any model.

On the basis of separated companies in Table 4 we can notice the following conclusion: examination of prediction capabilities by means of presented models can lead to significant errors in predicting bankruptcy. It is worth noticing that as many as three companies from the sample were identified by only one model, as being at risk of bankruptcy just one year before the bankruptcy.

3. UNIQUE FEATURES OF THE MOST EFFECTIVE MODELS

The most effective models of all models under consideation were Gajdek and Stos 3, Prusak 2, Prusak 4 and Appenzeller and Szarzec 1. The following calculation shows each model and function characterizing its component indicators [source 2, 10].

Gajdek and Stos 3Model

$$ZG = 0,20X1 + 0,0023X2 + 0,7809X3 + 0,965X4 - 0,3411X5$$

X1- sales / total assets
X2- liabilities / cost of products sold
X3- net profit / total assets
X4- gross profit / sales
X5- total liabilities / total assets

ZG < 0,44; implies a high risk of bankruptcy

Prusak 2 Model

$$Z2 = - 1,8713 + 1,4383*X1 + 0,1878*X2 + 5,0229*X3$$

X1- net profit + depreciation / total liabilities
X2- operating costs without pko / current liabilities.
X3- profit from sales / total assets.

Z < -0,295 implies a high risk of bankruptcy

Prusak 4 Model

$$Z4 = -0,3758 + 3,7657X1 + 0,1049X2 - 1,6765X3 + 3,5230X4$$

X1- profit from sales / total assets
X2- operating costs without pko / current liabilities.
X3- liabilities / total assets
X4- operating profit / total assets

Z4 < 0; implies a high risk of bankruptcy

Appenzeller and Szarzec 1 Model

$$Z = 1,286X1 - 1,305X2 - 0,226X3 + 3,015X4 - 0,005X5 - 0,009X6 - 0,661$$

X1- current assets / liabilities
X2- (current assets - stock - receivables) / liabilities
X3- gross profit / sales
X4- net profit / total assets
X5- (stock / sales) * number of days
X6- total liabilities / (operating profit + depreciation) * (12/ accounting period)

Z < 0; implies a high risk of bankruptcy

Building ratio analysis demonstrates the most predictive models show four indi-
cators are repeat. Three indicators are constructed from the net or gross profit and
sales. This means that authors of the construction of these models have focused on
company's capabilities to generate profit. Table 4 lists all the indicators appearing
in the four selected models: „1" show in which model a particular indicator occurs,
and indicators that are repeated were presented in bold.

Table 4. Extraction of indicators in the most effective models

Type of indicator /model	Gajdek and Stos	Prusak 2	Prusak 4	Appenzeller and Szarzec 1
net profit / total assets	1			1
total liabilities / total assets	1			
current assets / liabilities				1
sales / total assets	1			
gross profit / liabilities			1	
gross profit / sales	1			1
stock / sales				1
operating profit / total assets			1	
net profit + depreciation / total liabilities		1		
liabilities / cost of products sold	1			
Operating expenses excluding other operating expenses / average value of short-term liabilities excluding special funds and short-term financial liabilities		1	1	
profit from sales / total assets		1	1	
(current assets - stock - receivables) / short-term liabilities				1
total liabilities / (operating profit + depreciation) * (12/ accounting period)				1

Source: Own work.

It is worth noticing that the importance of these repeated indicators are the highest
and have a big impact on the outcome of specific model. Prusak Models 2 and 4 are
constructed based on indicators 3 and 4. As for the Appenzeller and Szarzec and Gaj-
dek and Stos 3 are constructed on the basis of indicators 6 and 5. It would be useful to
look at what is the relationship between these indicators and to consider their predic-
tive capabilities based on company's data.

CONCLUSIONS

Company's financial condition and thus the ability to sustain the activity, can be estimated by using the predictive models. In the literature there are many models, in this article however we compared 34 discriminant models on a sample of 100 bankrupt companies. Among the analyzed models, four models had the highest level of the appropriateness of the imminent bankruptcy of enterprises. The results showed that only the use of several models give satisfactory results.

The tested models are not perfect and using them can sometimes cause misjudgment because they are constructed with the help of financial ratios. Financial ratios are in turn calculated on the basis of financial statements, which means on historical data, that do not take into account the current state of the economy. It's worth noticing that the analyzed models are missing a market index indicator, i.e. index, which conveys current economical situation. There can be many of such indicators, but it's vital to choose those that rather quickly assess changing market conditions, such as GDP growth. Therefore, in the course of further studies on predictability of indicators, it is also important to research various indicators of changes in market conditions. Further studies will also look at all the indicators included in the selected four most effective discriminant models. The purpose of this analysis will be to check how much these indicators have predictive capabilities.

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INTEGRATING DISCRETE EVENT SIMULATION
AND FINANCIAL REPORTING

There are many gaps between practice of accounting and simulation modeling. Despite this, according to the literature overcoming these barriers is limited mostly to the integration activity-based costing method and manufacturing systems simulation models. The present stage of development of simulation tools has enabled modeling of start-up costs of resource use and costs that are proportional to the time of resource use. The author proposed a new approach to integrate concepts of simulation modeling and accounting for the generation of financial statements in production processes. It provides the ability to generate and analyze financial ratios. With this approach it is possible to generate not only easy to design items like revenue income statements, cost of goods, incomes, expenses or even activity-based cost but also the balance-sheet items such as payables and receivables and determination of cash flow account and a clear distinction on a cash basis and accrual accounting costs. Information and decision-making and even educational (matching principle) aspects of the approach are also important because the user model may at any time refer to the impact of economic events on financial statements and the financial ratios. It is also easier to observe the relationship between the value of financial ratios and delay time of accounts receivables and liabilities. The new integrative approach is the object representing the discrete events (eg sale or purchase) object multiplication to physical aspect object and book-entry form object. Examples of models that use the approach are presented and discussed.

1. LITERATURE REVIEW

Issues concerning the use of simulation approaches in the analysis of cause and effect, what-if analysis, and forecasting the impact of the decision of the options in the area of financial management in manufacturing companies are as follows: differences in mindset among accountants and engineers [3], the lack of formalization

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of the relationship between the material and financial flows [8] (despite the obvious possibility of treatment of the problem of cash management as an inventory problem with regard to uncertainty [1]), poorly understood relationships between cash position and planning in tactical or operational dimension [2]. One can assume that among the reasons for this state (that is the lack of creative thinking) are the ills of discrete event simulation environments curriculum [5] such as: focus on mathematical modeling, focus on applications of simulation tools, but are also described as the opposite effects of learning on the basis of simulation-based games leading to a stock broker license or start-up investment. At the beginning of the discussion it is worth recalling some basic concepts to which the author uses to describe the current state of research.

Simulation can be defined [6] as a design process of model (real or imagined system) and conducting experiments with the model (in terms of analyzing the results of the model and not the model itself). The objectives of the experiments performed in the simulation method is to understand the system and then examine the influence of different variants of decision on its operation. Thus the model should reproduce the actual system performance. After supplying the actual system input and input model similar values of decision variables should get similar results. The proposed advantages of simulation testing (evaluation of decision options) of the model in relation to research on the real system are: reduced costs, faster to obtain results, reduced risk, and other practical factors (eg, ease of operation, the ability to repeat the experiment for the changed data and input parameters). The computer simulation model is built is based on mathematical algorithms.

Discrete-event simulation (DES), formalized in the 70s by B. Zeigler, describes the operation of the system as a chronological (but recorded in varying time intervals) the sequence of events (changes in the system). A common application is therefore modeling of queuing systems. Concepts of DES are worth mentioning: event (a sudden change in the system), event list (during the course of the simulation events are generated / planned on a predefined schedule or randomly generated as a consequence of other events), activity-delay (keeping the event / facility for a specified time, for example, it represents the duration of the operation which may be deterministic, random or specified as to be a function of other variables such as type of object / event) and the current time in the course of simulation. There is also a delay of a different nature than previously described: the delay of the system state changes, which related to the state of the system resources such as waiting in line to service station (activity with a delay). DES modeling is now most commonly associated with building graphical mapping patterns of the basic relationships between objects and resources and sequence of tasks performed by blocks: generators, queues, delays, switches and exits. Although the implementation of DES using different approaches such as event-based, agent-based, process-based, etc.. from the viewpoint of a user creates a graphical model should not matter, unless he / she builds a custom function blocks (structural ele-

ments that require programming skills), or create hybrid models that combine approaches continuous simulation and DES.

Simulation approach in finance [2] includes, for example, cost models with particular emphasis on activity-based costing method, but it does not present financial flows by categories such as delay and depreciations, and does not include cash management issue that is crucial at the tactical level. The authors mention – they think – a small number of literature data on integration (not only in the simulation) financial aspect and physical (material) aspect. This is despite the fact that managers are of course aware of the relevance of the hypothetical integration tools, mainly due to the expected optimization capabilities. What's more, the authors noted the absence of application-event approaches discrete simulation system among advanced planning tools. Then proposed a general approach called advanced budgeting system, which consists of using and integrating a number of software applications through the Data Warehouse. Then apply it to study supply chain company, including the modeling tasks in ARIS and modeling of discrete event simulation in Arena and building a financial model in Visual Basic.

An example of a methodology to integrate methods of activity-based costing in the service systems with simulation models have been presented in [4]. Simulation modeling packages are equipped with the ability to record start-up costs of resource use and costs are proportional to the time of its use. The method of activity-based costing has enabled separation of costs used (loaded) the resources (eg service stations), costs associated with the performance of operations and cost objects. The costs of operations are assigned to objects related to operations. The simulation model takes into account the activity-based costing (ABC) method has the coefficients of the costs associated with the appearance of an object in the system and waiting for service and cost factors related to the occupation of "service station" and the residence time in the operating position of the object. Each object interacts with the system (its resources) records the amount of costs that are caused by it. In the ABC method, identification of problem is the relationship between cost drivers (how they change the cost of operation). Proposed in [4] methodology involves the use of one of data mining techniques as association rule mining. The aim is to identify previously unidentified relationship between cost drivers and estimate the necessary coefficients.

2. THE NEW METHOD

2.1. INTRODUCTION

Presentation of a new approach that integrates the concepts of modeling and simulation of accounting for the generation of financial statements in production processes

will involve show the several steps of production system simple model development. We begin by presenting assumptions of single server model. Based on simulation results, we discuss the behavior of revenue, a very important measure instrument of the economic system. Then extend the model assumptions for variable parameter periodically during the decision-making – the price of the product. Further extension of the model is to add the modules setting out costs and revenues, to determine the profit or loss as a function of time. Next model presents the most significant application of the concept of a new approach – the multiplier representation of the event (object) in two representations (object): material type object and an object of accounting type entry.

Will be shown how to model the extremely common economic phenomenon: liabilities repayment delay and how you can determine the current status of liabilities, which was until now a significant problem in simulation models. The next extension of the model assumptions will lead to show how the multiplication of an object in a stream of objects "in kind" will enable further modeling of economic phenomena: receivables repayment delay and, consequently, determine the current status of receivables. The summary will show the model can be extended to fulfill the following generalizing assumptions.

The presented models were made in Extendsim simulation package [7]. It was already in use in several author's previous work, such as presentation techniques for integrating simulation modeling approach and activity-based costing [9]. Modeling in Extendsim consists in placing the blocks (the model structure elements) collected from a variety of software libraries on the desktop application, assigning the values of their parameters, connecting blocks with a line to create and configure the model's structure and setting up experiments (advanced users can do it also with block structure). It is possible to construct separate blocks, or modify the existing operating rules and the grouping of blocks in hierarchical structures. Simulation experiment can be conducted with simultaneous graphical animation position between the blocks moving objects (representing events) or full speed without animation.

2.2. REVENUE RECORDING

In the first model, we show how to capture revenue in a simple (trivial) service system with a fixed price. We assume that the system has a single server, a single stream of objects coming into the system (orders for execution), the revenue will be recorded immediately after the object from the server (service station).

Assumptions: the intensity of the input stream of objects described by a random distribution: exponential distribution, the mean equal to 2 minutes. Execution time on server: uniform, real distribution between 1.5 and 2.5 minutes. Revenue per unit (price for the service): 5 units. The time course of the simulation : 100 time unit, the number of runs: 1. During construction of the model we have resolved the dilemma: how to accumulate (sum) revenue, whether or not to multiply the result of simulation – the

number of objects which have left the system by the unit price or summarize recorded (during the course of) the individual income. Because of the versatility (able to take into account the changing value of price) – we choose the second solution. Figure 1 depict the three parts of the model from the top: discrete-event model of service system, the model calculation of the total revenue and total revenue graph, chart constant unit price, and the graph signal event of sales. We observed fairly uniformly increasing values total revenue, as expected.
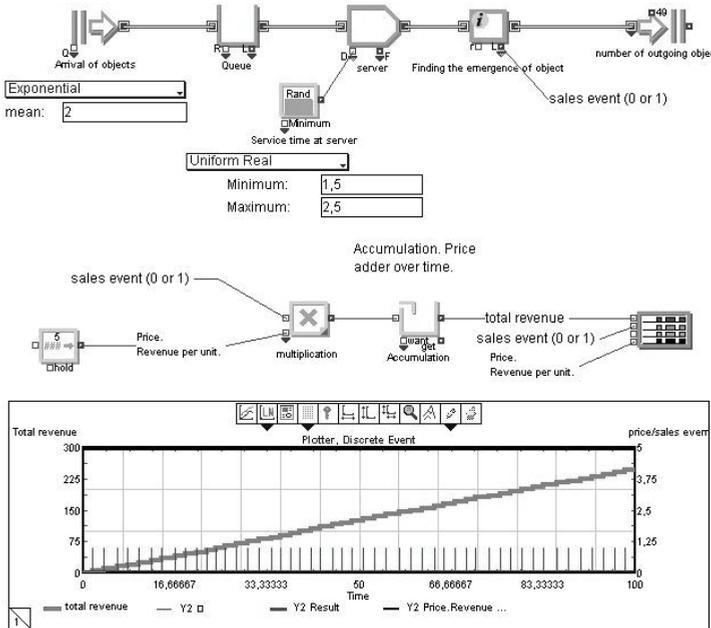
Fig. 1. Recording total revenue in the operating system. Calculation of income
by the sum of individual income

In the second model, we show how to capture revenues at above service system in a periodically changing prices. We take into account that the price during the whole process must remain non-negative.

Assumptions extended: the price varies periodically according to a sinusoidal course ranging from 1 to 9 units. The assumption of this type requires the use of block groups scaling sine wave as its amplitude and then moving up the value by a constant factor $(9 + 1)/2$, and this is equal to 5 units. Figure 2 depict the three parts of the model, from top: discrete-event model of a system service, a model calculation of the total revenue and total revenue graph, periodically variable unit price (signal event of sales has been omitted). We noted quite a growing total revenue, the growth rate increases with increasing prices and inhibited when the price is reduced periodically, as expected. In conclusion, it should be noted that the calculation of income (and as we see

in a moment the cost is the same) with a structure in which we multiply the revenue associated with the unit that appears at the output of the system object (or the price applicable at the time) by signal 1 or 0 and add to the sum of current income. This rather complex computational procedure is necessary due to the fact that the incoming object brings no information on individual income – this information is transmitted from the outside (not dependent on the characteristics of the object).
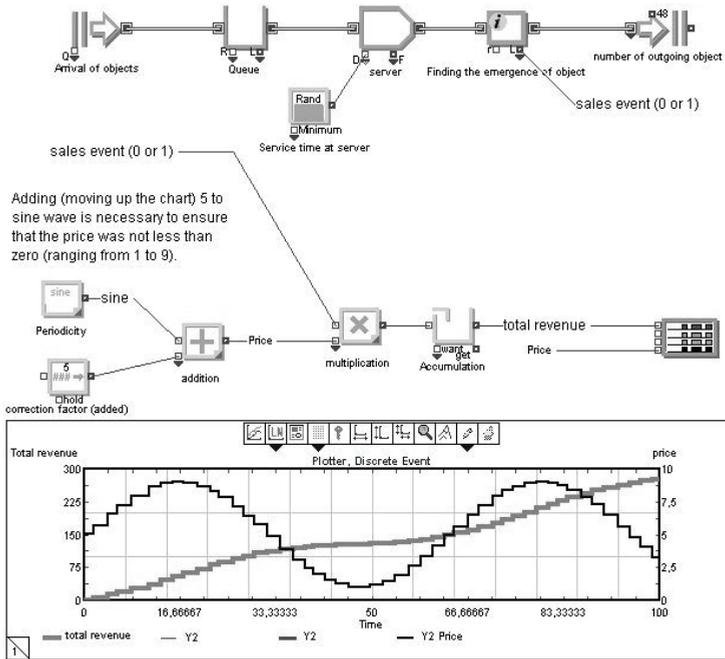
Fig. 2. Total revenue recording in the service system.
The model includes periodically varying the price

2.3. COST RECORDING

In the next model will be presented technique determining the costs associated with the acquisition of an object (for example – cost of materials). In the model we take into account the presence of different objects. We assume that objects (services) can be divided into two groups in regard to their unit costs and unit revenue. Knowing the designated total revenues and total cost will be possible to calculate the profit or loss. Of course, the position of the financial statements: income will take into account the total costs for all objects entered into the system but will record revenue only for the objects sold. Note that by assigning to each object its unit cost and expected revenue of unit it is possible for the direct determination (by summation) total cost and total revenue (do not have to take into account the type of signals 0 or 1. Extensive model

assumptions: the system come two kinds of objects (services) encoded by two colors: blue and red. The blue object the unit cost (acquisition) is 3 units and for the red object is 4 units. The blue object unit revenue (price) is 4 units and for the red object is 5 units. Probability of both types of object are the same.
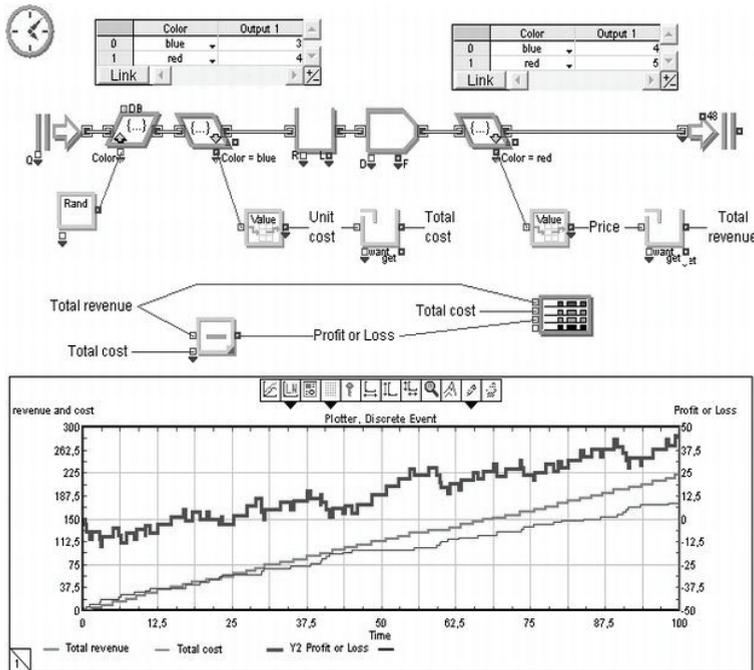
Fig. 3. Recording of total revenue, total cost and the profit or loss chart in service system for two kinds of objects characterized by different cost and revenue per unit

The cost is recorded before entering the queue in front of the server, while revenues are recorded after leaving the service station. The stream of objects (combined) has the same intensity as in previous models. The time required to operate as a service is independent of the type of facility and the same as before. Figure 3 depict the three parts of the model, from top: discrete-event model of service system, the model for calculating the total cost, total revenue and profit or loss and Chart Total revenue (medium thickness line), Total cost ((thinnest line) and Profit or Loss (thickest line). Note the fluctuations can be significant and Profit or Loss advantage of the situation "Loss" in the early course of the simulation. reason for this phenomenon is to delay recording revenue in relation to costs before the subject because "the product suitable for sale to" reach out of the system, must travel time service the server and wait in line sometimes. accumulated profit per unit (1 units for each object) in the initial period (about 25 time unit) is the predominant factor, and already in the subsequent minutes of the

profit accrued from the beginning of the simulation is "positive". If we added the observation in the model queue length, it can be noted that the faster growing "total cost" than "total revenue" (and consequently reducing the profit or even a showing of loss) when the queue length is high.

2.3. ESSENSE OF THE NEW METHOD

The following model presents the essence of the new approach: multiplication representation of the event (the object) to the two representations (objects): objects and things type accounting record type objects. Established model of economic phenomena called liabilities repayment delay. With the knowledge of the current state of total expenditures and total cost will calculate the current state of liabilities, which was until now a significant problem in simulation models. In the model, we leave all the previous assumptions, we add only the assumption of random distribution of delay repayment liabilities: Uniform, Real from 1 to 3 time unit. For readability, the resulting model of this study was divided into two parts: the part on currently discussed liabilities calculation (Fig. 4) and receivables calculation (Fig. 5). Left side of Fig. 4 shows hierarchical block containing part of the model (service model) for generation of input objects, and for calculating the total cost. In the model used for calculation of liabilities relationship between costs and total expenditure. Multiplication operation involves sending the output to both the block "multiplication" one object at this point, the appearance of the object "things" that have already been included in the calculation of costs. Each of these two facilities still carries the full information about the attributes (they have been prescribed no change). This makes it possible to calculate the single and total expenditure on account of liabilities arising from the cost incurred (but not yet settled) in obtaining the object to the system (in the upper branch of the model). Objects sent to the lower branch (without delay) to reach the next part of the model for the calculation of receivables.
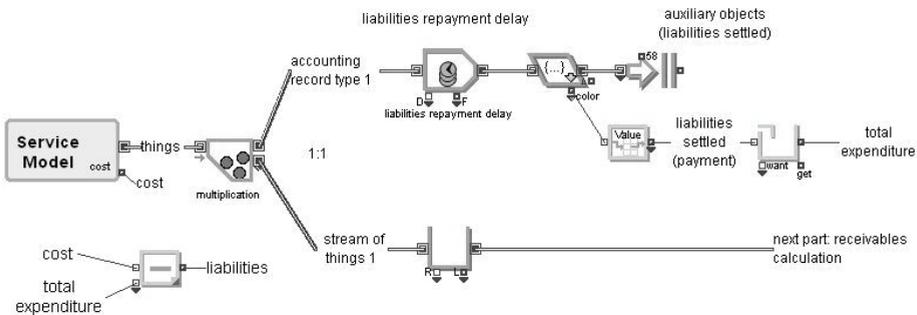

Fig. 4. Final model, part one: liabilities calculation. An example of a new method
– the calculation of the simulated total expenditure and the current status of liabilities

The following model presents a new approach for the calculation receivables. The calculations used economic phenomenon called receivable repayment delay. With the knowledge of the current state of total revenue and total income will calculate the current status of receivables, which was until now a significant problem in simulation models, as well. In the model, we leave all the previous assumptions, we add only the assumption of random distributions receivable repayment delay: Uniform, Real from 1 to 3 minutes. Multiplication operation involves sending the output to both the block "multiplication" one object at this point, the appearance of the object "things" that have already been included in the calculation of costs. Each of these two facilities still carries the full information about the attributes (they have been prescribed no change). This makes it possible to calculate the single and total income after taking account of receivables arising from the prices (unit revenues) for the sale of property (in the lower branch of the model). Accounting record type 2 objects after passing through the block to simulate receivables repayment delay, and after reading the attribute "color" will be sent to the upper branch and disappear from view. The lower branch of the model include stream objects of thing type.
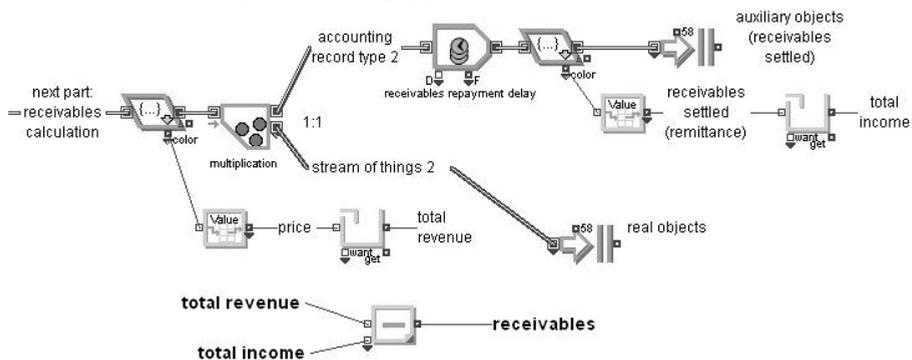
Fig. 5. Final model, part two: receivables calculation. An example of a new method
– the calculation of the simulated total income and the current status of receivables

2.4. EXPERIMENTS WITH THE NEW METHOD

In order to observe the results of the model, the experiment was extended to 300 time units. Moving average calculation was used for 100 time units. We see the advantage of moving average of receivables of the moving average of liabilities. It results in the advantage of the price over the cost of raising the height of the object (for both types of services). If you equalize its prices (revenue unit) and unit costs will cover the two graphs (results not presented in this paper). In the Fig. 6 are visible charts rapidly changing waveforms – it is a current state of the liabilities and receivables.

Next we check how receivables longer repayment delay will affect the simulation results. It was decided to change the values for the distribution of the interval from 11

to 13 time unit. The results are shown in Fig. 7 As expected, you can see is a huge
advantage averaged receivables above averaged liabilities, and a very large jumps of
the receivables. The reason for this situation is extension of the residence time of ac-
counting record objects type 2 within a Extendsim block Activity (receivables repay-
ment delay). There can be no increase in the value of total income at the time, and the
increase in total revenue has already taken place. This behavior can be regarded as be
one of the arguments for positive verification of the model and the new approach.
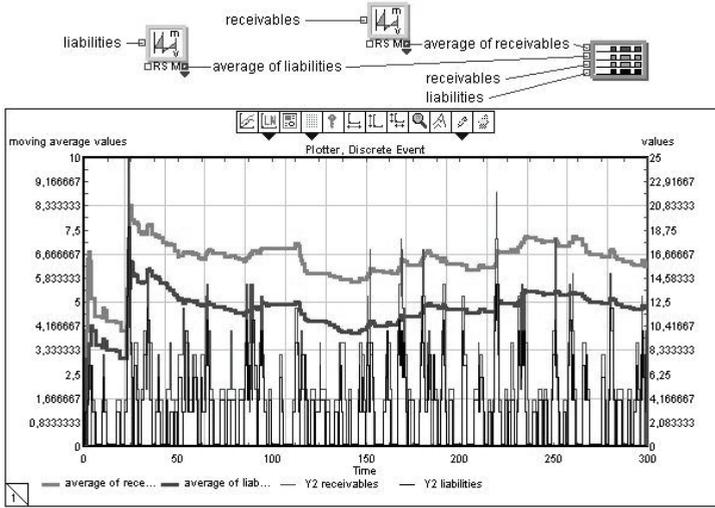
Fig. 6. Results of the model chart. Receivables repayment delay and liabilities repayment
delay distributions are the same
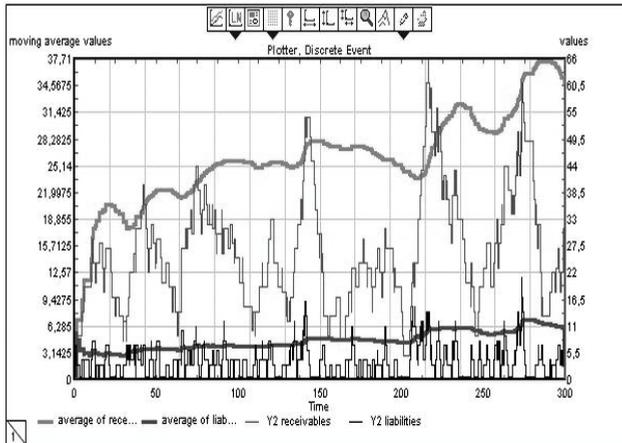
Fig. 7. Results of the model chart after modification.
Increase the receivables re-payment delay

2.5. SUMMARY

This paper presents an application of a new method for simulation and integration of financial reporting during construction service system model. The method can also be used in more complex conditions, for example taking into account the phenomenon of prepayments (not shown in this paper). It seems that it would be interesting to apply the method in the construction of the balance sheet and also on the model current account the company, which is needed to pay off liabilities and repaid receivables. Interesting results can also apply the method to other simulation packages.

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ECONOMIC VALUE ADDED A TOPICAL ISSUE FOR SCIENCE AND PRACTICE?

In the paper the existent achievements in Value Based Management (VBM), including especially those concerning Economic Value Added (EVA), were discussed. Various research areas were analysed from the point of view of potential problems that are important to be further investigated. Pros and cons of EVA and Market Value Accounting (MVA) relationship were indicated. In the area of performance reporting, a new measure EVA Momentum was elaborated on; difficulties concerning value measurement at the operating levels of management were emphasized. Potential problems that may appear during application of value measurement in motivation systems were also analysed.

1. INTRODUCTION

Value Based Management (VBM) has been the subject of research studies for over three decades. During this period, researchers have proposed coherent and comprehensive management theory indicating value creation as the major goal for business existence. Value Based Management includes (1) performance measurement and reporting, (2) valuation, and (3) motivation. As a result of long-lasting studies, business sciences offer management tools that constitute nearly complete guidelines for businesses aiming at their value growth.

Although Value Based Management is not a topical issue anymore, it is still present in business sciences and inspires new ideas. There are still new companies reported that implement new VBM tools. The value is still the focal point for most large companies. The subject of Value Based Management has not ceased to inspire emotions both among managers and researchers. Some consider it a revolution in management, others only a good management method. There are also voices of severe criticism indicating its seri-

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ous disadvantages and even implying it to be the source of the world economic crisis. It is worth emphasizing that despite ongoing debates, there are not any management methods that could compete with VBM and cohesively explain the sense and how business works.

In this article, I decided to restrict the Value Based Management to its most popular value creation measure: Economic Value Added (EVA). I substantiate my choice by the fact that the chosen measure is still the most often used one and is applied in various VBM areas. The goal of this article is to answer the question whether Economic Value Added is a fully explored subject or there is still something worth investigating. If there is still something to study then which areas of VBM does it concern.

While answering the above question, I used the newest literature, my own survey data, and analyses of polish companies that use Value Based Management with Economic Value Added.

2. ECONOMIC VALUE ADDED – AREAS OF APPLICATION AND RESEARCH

VBM is not only a management theory but also a philosophy of business. It considers value the most important factor in strategic, operational, economic, and investment decision-making. According to Szczepanowski, creating value integrates the mission, objectives and strategies into one coherent system. A system that demands full cooperation of all management levels in tasks and responsibilities' formulation at the level of the whole company, strategic units, and operational centres [21]. Since VBM became commonly used, value has been the major gaol of business existence. Survival and development of a company depends on the ability to multiply the value of invested capital. Under conditions of constant capital migration, companies, or rather managers, face the need for continuous competition not only for customers but especially for investors. VBM indicates that capital is a finite resource essential for proper business functioning, a resource that costs money. The business risk determines capital cost. Therefore VBM includes interests of every stakeholder, not only shareholders but also employees, customers, countries, and even environmentalists. More than average profits at higher risk do not increase business value because the actual profits do not meet higher owners' expectations, which express themselves in higher capital cost.

The idea of including capital cost in performance measurement realizes EVA, which can be defined as: **EVA = NOPAT − IC x WACC** or **EVA = (ROIC − WACC) x IC,**
where:
EVA – Economic Value Added
NOPAT – Net Operating Profit After Tax
WACC – Weight Average Cost of Capital

 ROIC – Return On Invested Capital
 IC – Invested Capital [1], [18].

EVA compares expected profit with realized profit, i.e. expectations of the investor with what was worked out by the company. The concept came into being in 1991; in this year 'The Quest for Value' by G. Bennett Stewart III was published. Next a series of articles on Stern Stewart's company made the new concept EVA and MVA famous. Especially, the article published in 'Fortune' is noticeable as it named EVA 'the real key to creating wealth' [18].

It is worth noticing the phenomenon of EVA. The concept drew considerable attention of both practitioners and researchers. Certainly, applicability is the measure of the concept quality, for details see Will Seal's cultural cycle of capitalism that explains the phenomenon of gaining popularity by VBM, but what truly made the concept successful was the cooperation of scientists and researchers. In order any management concept to be successful none of the elements in the cycle in Fig. 1 should be missing, but the cycle can started from either of the elements.
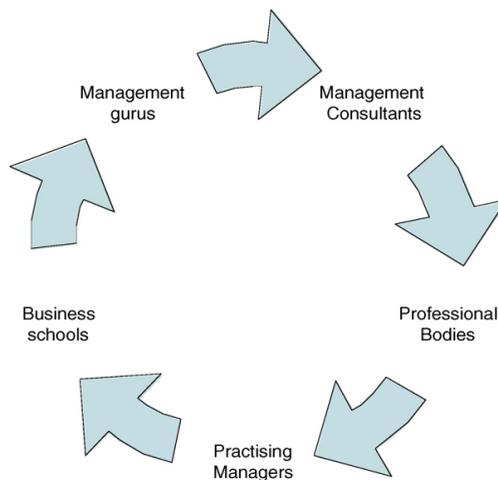
Fig. 1. Institutions in the cultural circuit of capitalism [16]

Sharma Anil and Kumar Satish indicated subsequent EVA research areas:
− EVA and stock returns and EVA – MVA relationship,
− Value based management (VBM) / reporting systems, value drivers etc,
− Managerial behavior and performance management,
− Concept, criticism & implementation, EVA – adjustments etc,
− Discounting approaches– EVA relationship to NPV and DCF valuation [17].
Below I discuss the indicated research areas.

2.1. RELATIONSHIP BETWEEN EVA AND MVA

The relationship between EVA and MVA is extensively studied by researchers. The developed theory allows through cause-effect relations to explain how EVA is linked to market value. It even allows to estimate by mathematical relationship EVA changes, which are expected by the market at a given share price. It might seem that the theory answers the eternal question and goal of every manager: what to do in order to increase share price. But is it enough to cause worked-out EVA to be better than the expected one calculated on the basis of a current share price? Because theoretical considerations have been put into practice, without difficulty one can find examples of relationship between market to market and EVA. For example G.B. Stewart III in his article (2009) cites the market to market and EVA relationship for Emerson Electric Company (Fig. 2).
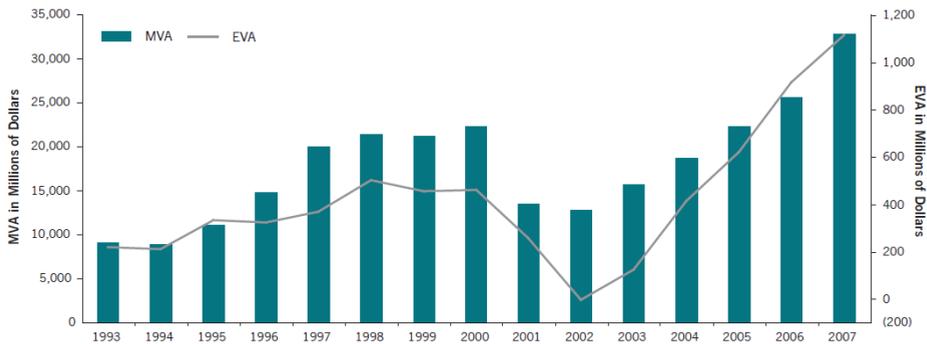
Fig. 2. EVA-MVA relationship for Emerson[19]

Unfortunately, the theoretical assumptions are not always confirmed by empirical studies. The voices among scientists are split. Lehn & Makhija [10] proved that EVA has the strongest correlation with rate on return among all measures of business activity. Stewart [18], Medeiros [4], Worthington, and West [20] similarly showed EVA to explain better behaviour of share prices than other economic measures and that the rate of return on shares is better correlated with EVA than with profit or FOCF. Moreover, Machuga et al. [11] also indicated that EVA measure can better support behaviour of share prices in the future. However, there are a lot of studies with quite different results, indicating VBM measures not to explain the rate of return on shares, including EVA. Peterson and Peterson [13] showed that traditional measures assessing business condition are not significantly weaker correlated with rate of return on shares in comparison to VBM measures. Fernandez [5] performed correlation analysis between EVA and MVA on 582 American companies. In 296 cases NPOPAT showed weaker correlation with MVA than EVA; in 210 cases a negative correlation was identified between EVA and MVA. However, as the

supporters of VBM theory emphasize that the Economic Value Added measurement should not be done on the basis of data coming from financial statements, because some improvements are needed. The question arises: what kind of improvements were introduced by authors of the above studies and whether they were chosen correctly. The debate has not been settled yet.

The vision of EVA as a measure that allows to associate daily managers decisions with share prices has taken deep roots in managers' minds. As a result, motivation systems based on Economic Value Added can be preferred by many researchers and consulting companies. However, it does not change that the debate about relationship between EVA and MVA seems to be far from settled. The factors interfering the above relationship are still unknown.

2.2. EVA AS A TOOL TO EVALUATE BUSINESS PERFORMANCE

Value management demands efficient value measurement and reporting. Performance measurement and reporting is one of the three key elements of VBM, mentioned in the introduction, and constitute a very important research area in VBM and EVA. Management with EVA is suggested by many value generating strategies. From operating strategies, known and used before VBM, through invested capital strategies (e.g. capital expenses, inventory and receivables management), or M&A strategies, to risk and capital cost management. EVA-based VBM systems are depicted as trees of value drivers, in which through disintegration of EVA next value drivers can be determined. Such an approach allows to identify how every single element associated with EBIT, tax, or Invested Capital influence EVA. Although such solutions have been known to science and practitioners for a long time [3], [18], [21], [22], literature analyses and VBM applications allow to state that still many questions are unanswered.

There are still many ongoing studies of new measures based on EVA that better reflect the business ability to multiply value. It is worth mentioning e.g. a new Steward's idea i.e. EVA momentum [2], [19], defined as: EVA Momentum = (EVA t – EVA t-1)/ Sells t. One gets impression that the proposed measure directly refers to the relationship between EVA and MVA: in the counter appears delta/change in EVA. According to Steward delta EVA allows EVA to be applied also to businesses that in a given period of time generate lower value, for which EVA is negative. As a result the measure is independent of past decisions and cuts off from wasted costs in previous years; it is future- and strategy-oriented. The decrease of Eva Momentum may be indicative of upcoming strategy crisis due to the burnout of the company strategy. Applying delta EVA measure is part of emerging VBM trend that a company should compete with itself, and thus constantly improve itself. This could be a separate research area in VBM studies.

Steward indicates as an advantage of EVA Momentum the fact that it is based on the known factor i.e. sales from previous period. As a result according to Steward,

managers cannot influence business performance as it was in the case of traditional measures, like for example profitability rations. It is difficult to have positive EVA Momentum. It demands to implement strategy of good development i.e. to increase sales at the same time increasing EVA. It is hardly possible to imagine long-lasting increase of EVA while the company decreases its activity. Steward presented studies focused on analysis of the measure for 3000 biggest American companies. They revealed that the average value of the measure is close to zero. The companies with the highest EVA Momentum belong to the fastest developing industry branches such as biomedicine, IT, including Google and Apple. How to build EVA momentum? The answer proposed by Steward is the tree of value drivers. There are two key elements that condition satisfactory EVA Momentum value: efficiency gains and profitable growth. The recipe for business seems to be easy: effectiveness increase and growth. Steward proposed the tree of factors that shape both of them calling his proposition a new DuPont formula.

Steward's idea is definitely worth considering by researchers. Subsequent directions for further analyses may be formed:

- valuation of new value measures form the point of view of the investor,
- looking for strategies generating positive EVA Momentum and identification of strategies leading to negative measures,
- implementation of the concept.

EVA Momentum seems to be an interesting idea to evaluate business performance from the point of view of investor; however, it does not satisfy all VBM demands. For example, it does not satisfy the demands of operating managers looking for value growth on the basis of their daily decisions. EVA and EVA-based measures can be easily measured, compared and valuated at the level of company as a whole but their applicability at lower levels of management seem to be limited or even impossible. According to Kasiewicz [7] the most important difficulty in VBM implementation is unclear measure of workers and managers activities. If the rules how to create value are not understood on the daily basis, the accepted VBM measures do not change workers and managers behaviour and do not generate growth of company value. The necessity to look for possibilities of measuring and reporting at lower levels of management seems to be still topical issue for researchers. How to estimate EVA of a contract, client, or any other level of operational management where the value is build but where lack of formal financial reporting to do proper evaluation according to EVA methodology is apparent? Not without reason did I use the word 'estimate' because it will be rather allocation of capital cost than measurement on the basis of unambiguous register. It seems that the difficulty lies in the allocation of capital cost to the organizational area for which it is responsible. The research studies suggest a few possible solutions. Firstly, allocation of capital cost to the smallest centres of value and looking for drivers that could best allocate them. Special role in this research plays processing approach [6], [8], [14], [15]. Secondly, making simplifications, i.e. by evaluating value centres, taking into account only selected positions of invested capital (for example, fixed assets, performing receivables by evaluation of value creation in de-

partment or plant of the company). On many occasions such assumptions may be proper for good value management. This area without doubt needs further research:

– many problems associated with transfer of EVA measurement to lower levels of management are unsolved; there are not unambiguous recommendations and procedures associated with value measurement at the level of smallest value centres. As a result, motivation systems at lower levels of management are not connected with those of higher and investors' expectations,

– the existent attempts of transferring value measurement to lower levels of management, apart from operational performance, concentrate on capital allocation and its cost, not including issues connected with risk characteristic of a given EVA area,

– calculating difficulties connected with reporting and EVA measurement in the middle of the year; in case of operating systems that are to support daily/monthly value management reporting on the basis of annual data is not enough.

2.3. EVA AS A TOOL THAT SHAPES MANAGERS BEHAVIOUR

The philosophy of value management can be realized only if the value will be the aim of daily employee activities and decisions. Employees will be concentrated on value creation if their performance evaluation and payment is dependent on value measurement. Because of that, the third key element of Value Based Management is motivation and bonus system. Business sciences in this area proposes many solutions, from stock options to bonus systems based on performed EVA. Literature analyses and my own experience indicate that Economic Value Added is most often chosen by companies that decided to apply VBM philosophy although the percentage of this companies is not large. O'Byrne et al. Included in their studies companies from the list of 1500 S&P. The most common applied measures in motivation systems based on revenue (31%), EPS (29%), and EBIT (28%) [12]. 15% of all analysed companies used in their motivation systsems value based management measure, including 45% EVA. My research studies based on 250 companies from the list 500 'Rzeczypospolita' allows to identify 7 companies that use VBM measure, which constitute 12% considering that 47 questioners were answered [9].

Studies associated with shaping of managers behaviour look for ideal bonus systems. There are propositions of bonuses based not only on EVA but also on delta EVA and even on the difference between performed EVA and EVA expected resulting from investor expectations and actual market value. Financial measurements are enriched in factors concerning individual tasks and strategic goals. Other studies focus on how to decompose motivation systems to lower levels of management. Moreover, motivation systems based on value management are to encourage managers to various behaviours e.g. internal and external benchmarking through association of the bonus with EVA at higher levels of management; long-term value creation decision through mechanisms of bonus banking. Motivation systems became a tool in a game between managers and the board of directors. Managers concentrate on how to use, for their particular goals, the weakness of the

current motivation system while the board concentrates on how to create more sophisti-cated ones.

The main problem in the use of Value Based Management in motivation system is that it is unreliable in critical moments for organizations. O'Byrne et al. indicate examples of big American companies, where board of directors decided to withhold bonus systems in cases of strategic problems, decrease in financial performance and also EVA performance [12]. While there are significant decreases or increases in performance, value-based moti-vation systems are not working. Especially the vision of loss of key managers makes the owners and boards of directors to apply exceptions to formerly prepared motivation sys-tems and bonus formulas.

The subjects of VMB application in terms of motivation systems are surly still interest-ing for researchers. There are still unanswered questions about:
- existence or lack of borders in growth of business value and possibility to achieve still positive delta EVA,
- possibilities to use sector and market adjustments in bonus systems, i.e. looking for estimation methods influencing market and sector factors on business value, EVA, and possibilities of considering this influence in motivation systems.

1.2. EVA IMPLEMENTAION

The way of measuring value is of uttermost importance, especial for people whose bo-nuses depend on it. In this way we arrive at the value research area associated with value measurement. Even if we focus on EVA, it should be indicated that its measurement, al-though it seems easy and readable, is not clear at all. Financial reporting not always re-flects business, which can be easily found in literature. Stern&Steward indicate potential 168 corrections to their financial reports, which are worth considering at determining value measurement. For example, balance sheet law orders to classify some elements as costs while business sense orders to treat them as investments. Such issues should be con-sidered at value measurement. Experiences with VBM systems indicate that every sector has its own specific requirements at value measurement. One would like to apply different adjustments in manufacturing company, services, and developer. The list of corrections seems to be unlimited. Moreover, changing in balance sheet law causes the necessity of considering new issues. The problem seems to be with implementation rather than consti-tute a subject for researchers, but it cannot be ignored by both managers or scientists using Economic Value Added.

2. CONCLUSION

Throughout many years of propagation and research, the VBM concept became deeply rooted in minds of managers and business sciences. On one hand, the statement that science has not yet proposed an alternative, cohesive management concept that explains the sense of business existence can be uttered. Economic Value Added was to be an easy and readable tool even for non-financialists that indicates the direction of activities, allows to measure, evaluate and reward obtained results. On the other hand it seems that the mechanisms used by EVA are based on oversimplified description of reality and thus are not flawless. However, I have not identified in literature any important propositions that would extend or modify the basic EVA concept. Therefore it seems reasonable to further investigate it. This article indicates at least some of the areas to be studied:

– lack of tools to measure and mechanisms to manage value at lower and operational levels of management i.e. where the value is build,
– modification of unreal pressure to constantly build more value (positive delta EVA) incorporated into VBM philosophy,
– taking into consideration at value measurement factors connected with economic situation,
– inclusion of risk factors other than financial risk included today into value measurement.

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DYNAMIC DISCOUNT RATE IN ESTIMATING THE INVESTMENTS PROFITABILITY – CONTRIBUTE TO THE DISCUSSION

The work is about estimating the investments profitability, especially taking the discount rate into consideration. The first part of the work focuses on common known and used information connected with investment and investment division, with a reference to well-known methods, used in decision-making process connected with the investment accomplishment. The second part of the work is about the critical attitude of using static discount rate. Despite the fact that many authors agree about it, in practice it is assumed that the discount rate should be static when it is used to lead cash flows to the paralleled period. It will not reflect the real change of money value in time. Taking into account the influence of many factors that changes in time, using dynamic discount rate, it is proposed to be used in estimating the investments profitability.

1. THE POINT OF INVESTMENT

Generally the term "the investment is comprehended as costs to build(-up) re-sources (…) that are the object of investment" [7]. With extensive grasp, investments are "economic costs to create or widen capital assets. The build-up of capital assets and their better use allow to enlarge the national income and satisfy social needs much more" [22].

In financial point of view, the investment means „resources (costs) of definite pur-pose, which means, they should get new estate objects or enlarge the existing ones"[9].

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Such a conception is developed by Gawron. He claims that investments are "purposely expended company assets to enlarge its future incomes. Investments creates or enlarge tangible assets, financial assets or intangible assets of the company by using finance" [3].

The accountancy act reads that the investment means "assets vested to get economic profits from increase of the assets values, obtaining incomes as interests, dividends (shares in profits) or other benefits, including commercial transaction, especially financial assets and those estates, intangible and legal assets which are not used by entity but they were vested to get profits' [17].

The definitions of investment above are equivocal. They describe both process and the result. Hirshleifer indicates that the investment is a venture which point is „a present sacrifice for a future profit. The present is relatively certain. On the other hand the future is unknown. That is why investments immolate certainty to uncertain profit" [6]. Walica has got a similar point of view. He thinks, the investment is "a present renouncement of consumption to get future benefits" [18]. Rogowski explains it more widely. For him, an investment is "a long-term, risky allocation of economic resources (investment assets) in order to get benefits in the future". Despite of existing many characterisations that descrive what an investment is, it should be taken into consideraton that there are also features which determine, whether the economic event can be called an investment. Those features are: capital expenditure, time, profit and risk.

On the basis of Hirshleifer's definition, there are three fundamental features or investment activity [2]:

Psychological element – it is resignation from present consumption to future, uncertain profits;

Passage of time – it is an inseparable part of the investment. When we make an investment, present goods are immolated to future effects, so we put the benefit off;

Risk taking – benefits for an investing entity can, but do not have to be found in the future. The entity takes risk because an investment does not have to yield expected profits and even causes loses.

THE DIVISION OF INVESTMENTS

Investments can be divided because of several points of view. It could be classified by origin, diligence of expected effects, the kind of possession, the kind of investor, country of investor's origin, economy sector [13,18]. However, one of basic classifications expresses the investments as: financial, intangible, tangible and investments in human capital, which become really important in times of economy based on knowledge.

Financial investments, also called capital or indirect ones, mean capital alloca-tion which is funds or fixed assets in another economic entity. It aims to get income as interest, dividend or increase of capital value. The most common financial in-vestments are connected with buying securities but also with buying company shares or bank deposits. On the other hand, intangible point of investment means all expenditures for research and development area, advertising, personnel training and social welfares [15]. On the other hand, tangible investments are connected with buying fixed assets, which is used to generate incomes. Tangible investments are also called direct ones and aim to enlarge the scale and scope of company activity as well as enlarge its profitability, and improve its competitive position [15, 21].

Tangible investments are buying fixed assets and exploiting them to get income. Financial investments are recognized by buying securities, companies' shares, for-eign currencies and savings allocation on bank accounts. Expenditures on develop-ment of human skills are found as special kind of investment. The effects of expend-itures on human skills are difficult to measure. But it is sure that they yield measurable benefits [20].

CLASSICAL METHODS OF ESTIMATING
THE INVESTMENT PROFITABILITY

The decisions connected with taking the investment or not are crucial for a com-pany. The accuracy of investments decisions oblige positive effects for a company. To assess properly planned or possible investments, investors bases on available methods that make the investment evaluation easier. The evaluation or estimation of the investment is taken by considering its efficiency, which are relations between obtained effects to borne costs. The methods of estimating the investment profitabil-ity are helpful.

NPV and IRR methods are the most known and generally used. Both comes from a group of dynamic methods, also known as discount ones (taking the time passage into consideration). The base of these methods is to determine incomes and out-comes defined as cash streams, generated by estimated investment venture [20].

The net present value method (NPV) is "the sum of net present cash flows val-ues (cash surplus) minus primary expenditure" [12] The method allows to define the value of difference between discounted flows of incomes and outcomes, for each year separately [16]. The method is described by a formula:

$$NPV = \sum_{t=0}^{n} \frac{NCF_t}{(1+r)^t} \qquad (1)$$

where:

NCF_t – net cash flows,

$(1+r)^t$ – discount factor, where „r" means discount rate,

$t = 0,1…n$ consecutive numbers of years

The profitability of estimated investment venture is determined by not negative value of NPV factor.

The second most common method is the internal rate of return (IRR), which means "such a discount rate that equalizes discounted flow of financial incomes and discounted value of investment assets" [13]. In other words, it is such a discount rate for which NPV = 0. IRR shows the profitability of examined investment, which relies only on cash flows in a company and not on shaped discount rates in the market. Accepted capital cost of examined investment is determined by this method. IRR factor is presented by formula 2:

$$NPV = \sum_{t=0}^{n} \frac{NCF_t}{(1 + IRR)^t} = 0 \tag{2}$$

Unfortunately, the mentioned methods are not faults-free. In case of IRR, one of mentioned faults is the possibility of existence more than one IRR rate – it happens when we have untypical projects, where negative cash flows could happen not only at the beginning of the project but also in its duration. Another difficulty is a fact that the estimated investment could not have IRR which equalizes discounted flow of incomes and discounted flow of costs. Therefore NPV is connected with such problems as different calculations of cash flows (direct, indirect and simplified) or this, what is really important, when we consider investment projects – dissimilarity of the discount rate calculation.

A common problem for this group of dynamic methods is acceptation for constant discount rate in the whole period of a venture progress. Acceptation for such condition of the discount rate does not reflect the real loss of money value change in time. The attempt to solve this problem was to propose a variable discount rate – the formula no 3 is showing this problem:

$$NPV = \sum_{t=0}^{n} \frac{NCF_t}{\prod_{i=0}^{t}(1 + r_i)} \tag{3}$$

NPV method with variable discount rate is said to be greeting for dynamic methods but it is not fully satisfying solution. For one period, the discount rate is still constant.

In the reference books in Poland, the issue of investment estimation by non-classical method comes into prominence in the meantime. But those are studies which can be called the methods of expanded estimation investment analysis. There are risk-adjusted performance measures of return rate, gains-to-losses measures and other measures of external elaboration and widely implied model approach. Unfortunately, none of these do not show the dynamics of the discount rate. In the Polish reference books, only Gajka and Kaluszka propose average discount rate but, because they base their research on pension fund, there are many flaws:

- the research considers only information about open pension fund market
- it considers short investment horizon
- it considers the dependence upon funds in the market
- financial risk, inflation and other external factors are not considered
- there is no research on effectiveness of this method or its implementation in tangible investment range and other capital investments

2. THE DYNAMIC CHARACTER OF THE DISCOUNT RATE – THE RELEVANCE OF CONSIDERED ISSUE

The discount rate is „a measure of used interest rate, which should be gained to pay credit interests or to balance alternative deposit interests which was cancelled to invest assets and cover the benefit for risk". [10] In dynamic methods, the cost of capital is the discount rate which is used to lead cash flows to present moment. In the reference books, the cost of capital is defined as an expected by investors return rate from invested capital [1]. Invested capital can come from own financial sources or from external ones. Generally, the companies use both internal and external sources. That is why the optimum set of different kind of foreign and own capital, together with the cost of each element, is to establish weighted average cost of capital (WACC) [14].

In the books, it is more often underlined that constant discount rate will prove useful in stable economy, where the inflation is in constant level. Unfortunately, Polish economy cannot be called stable, moreover instability of economy situation is reflected by economic crisis.

Furthermore, the aim of every company is to maximize its own value. It could happen i.a. by investment. So, investment should be estimated most precisely because it is really important and the discount rate influences the value of conducted estimation very much.

It should be remembered that each company works in a dynamic environment and it causes that every investment is influenced by many factors that changes in time.

Variable factors essentially influence making the right decision, which is especially reflected by estimating discount rate. As it has been mentioned, the most common discount rate is WACC. The discount rate fixed in that way, which is established in advance and does not change in the investment lifetime would come true if the cost of foreign and own capital was stable and the structure of investment fund did not change in the future, which is not sure. We cannot predict if the investment realization need to incur new covenants, which strongly affects the structure of invested capital. The increase of debt charges causes not only the increase of using cheaper capital, as which foreign capital is regarded, but also the increase of own capital cost. The next unstable element that influences the value of the discount rate is inflation. In the company inflation is of a great importance because it influences the creation of products prices and costs, which increase in different rate when inflation happens, and it causes different rate and trends of changes in the structure of company income and costs. Moreover, the result of inflation chances could be e.g. the increase of credits interest rates. It is of a great importance in case of company funding investment with floating rate credit.

PROPOSED MODEL TESTS

Tangible investments are generally realized in a dynamic environment and it is related to long-term perspective. Uncertainty about future conditions, that could radically change in the time passage, is getting increase in the course of venture time, which can influence accuracy of investment estimation. Despite awareness of dynamic environment, in the reference books, there is a solution to use constant rate that discounted cash flows. Considering the influence of many factors, that can differ in the future, variable discount rate is proposed to be use because of its dynamic character. It could be a more precise measure that reflects the actual situation of predicted market status, which changes in the time passage.

The science gives us a lot of possibilities to try the discount rate estimation, which could have dynamic character. We should pay attention to differential calculus in discrete mathematics, regression use or option pricing, especially Black-Scholes model for European sales option, particularly the algorithm of comparative price, change in the unit.

The first approach, that should be concerned, is differential calculus in discrete mathematics. It is used to calculate the given sum in a systematic way [5].

Regression use is an obvious idea, because econometric models do not only describe interaction between examined features but they are also used to predict the maintenance of modelled processes [4].

Another approach, concerning the similarity between financial options and tangible investment, is using option pricing. The analogy between financial options and tangible investment is presented in the table 1 [11].

Table 1. The analogy between financial options and tangible investment

Investments	Options
Cash flows	Value of basic instrument
Investment asset	The price of making
Net profits of the project	The value of options
Time needed to take action connected with investment realization	Option empire time
Variation of cash flows generated by a company	Variation of basic instrument

From the estimation of dynamic discount rate point of view, the crucial element is the aim of options pricing. which means to set a price of instrument in any moment and to assume that the market works in a continuous way. The protection against price change, which can be caused by option pricing, is a reliable reference to propose the dynamic discount rate, which is influenced by factors changing in time. Additonally, browsing the issues of option pricing, it is difficult to omit the models of term structure that base on evolution of temporary interest rate. It can be also an interesting issue in the context of deliberating the discount rate [20].

BLACK–SCHOLES MODEL

The next approach is using Black–Scholes model based on a theory of quantum mathematics that was used to multiply profit during the creation of a dynamic return rate model. The model is an answer to a Soroz theory of reflexivity which says, that financial markets cannot be efficient and rational in 100% and prices reflects ignorance and lack of common sense of millions of investors.

$$P = \mathrm{X}e^{-rT}\Phi\left(\frac{-\ln\frac{s}{x}-\left(r-\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}\right) - S\Phi\left(\frac{-\ln\frac{s}{x}-\left(r+\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}\right) \qquad (4)$$

P – the price of options sales

The price in the moment of realization S_T is an inevitable random variable

The expected profit value of option realization amounts:

$$E(S_T - X)^+ = \int_X^{+\infty} (S_T - X)P(S_T)dS_T \tag{5}$$

Because money can be given after the lapse of set time, a modification should be accepted: 1 monetary unit invested in risk-free investments after lapse of time T is worth e^{rT} and the options value is e^{rT} times smaller than the expected profit:

$$C = e^{-rT} \int_X^{+\infty} (S_T - X)P(S_T)dS_T = e^{-rT}\left(\int_X^{+\infty} S_T P(S_T)dS_T - \int_X^{+\infty} XP(S_T)dS_T \right) \tag{6}$$

The price of a share $T-$ in time is a random variable.

The logarithm of a relative change in a unit of time is random variable, that is distributed with a good approximation, normal with a standard deviation equals σ and the average, that equals average rate of return from the investment in the market – $N(r, \sigma^2)$.

$$Y_k = \ln\frac{S_{k+1}}{S_k} \tag{7}$$

3. SUMMARY

In the work, the issues connected with estimating the tangible investment profitability was raised, especially the discount rate, which is used to lead cash flows to the paralleled period. It is assumed that the discount rate is set in advance and on the static level, in the whole period of the investment. Unfortunately, information used to estimate the discount rate can change dramatically in the future. This could influence the results of conducted investment. The instability itself and the lack of confidence that the factors, considered in the investment estimation, will not significantly fluctuate are the base to agree with the opinion that discount rate should have a dynamic character. The authors of the work are mentioning several propositions that could help to define the dynamic discount rate in further studies. The common fea-

ture of presented solutions is a relation to continuous processes , which is then the base to set the discount rate variable in time. Dynamic environment, in which every company works, makes it impossible to eliminate risk (which is a measurable form of uncertainty) of factors change, which influences the estimated discount rate. However, the proposed model tests could let to reduce it, which will influence the precision of the estimation of examined tangible investment.

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Paweł ANDRZEJEWSKI*

DEFENSE STRATEGIES AGAINST HOSTILE TAKEOVERS: AN ANALYSIS OF THE MOST RECOGNIZED CASE STUDIES IN POLAND

The dynamic growth of the global economy, development of transport and decreasing trade barriers, have contributed to the emergence of more and more global companies, and thus the development of mergers and acquisitions market. Many managers have decided to purchase, or merge with companies that have significant strategic resources or knowledge. This resulted in a parallel development of defensive action, by corporate boards not wanting to lose the independence.

The paper presents selected case studies of merger and acquisitions, their history, description of the defense and effects of the defense. The greatest emphasis was put on the clarification of issues related to hostile takeovers, and ways of defending against them. The analysis has been made of the most famous takeovers, and on this basis the recommendation for the managers of Polish joint stock companies was created.

INTRODUCTION

There are many reasons why companies merge. However, most cases are based on economical motives. Often, the merger or acquisition of an entity helps to gain market dominance, or even dictate prices. The problem arises when the strategic plans include aims where the company does not want to lose independence and be incarnated. Often the only solution in such a case is to approach the shareholders with a request to attempt to remove the cumbersome management. The costs of such operations can be large, but often managers are willing to pay any price, in order to pursue important long-term business strategies. Experience shows that when further negotiations do not produce results, the board usually is willing to resort to a hostile takeover, if it helps to:

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• facilitate expansion into new markets,
• acquire new distribution channels;
• Increase participation in the industry;
 • acquire essential know-how and/or patents, or
• broaden the product range.

It is also vital to recognize the financial situation of the main goal and whether it will be accepted positively on the market. On the other hand, there are plenty of actions, that the target company may take up to prevent the acquisition or, in cases where it is very difficult, they may have tactics to strive to increase and obtain the highest possible final price. To better understand these mechanisms we will review the case studies of Kruk and Bogatynki acquisitions.

1. ATTACK OF VISTULA & WÓLCZANKA (V &W) ON KRUK

THE HISTORY OF THE ACQUISITION

Wojciech Kruk, a manager of the most famous jewelery company in Poland that holds 160 years of traditions, was on the verge of losing the family business in May 2008. Prior to May, Kruk exercised the option to sell their shares. In order to gain a considerable profit, they took advantage and sold their stocks which dropped their shares below 50% and resulted in a threat of loss of control.

Raphael Bauer, the former president of the group-Vistula & Wólczanka decided to take advantage of this situation[1]. Vistula & Wólczanka was one of the leading companies in elegant clothing for men, but was planning to expand their range of products to include gold jewelry. The acquisition was fostered by the fact that Kruk was a known jewelry brand with a well developed sales network, as well as the financial crisis, which reduced the price of all shares on the stock exchange. The absorption of the jewelry industry leader seemed to be inevitable. W. Kruk did not have the means to defend its position; the family controlled only 28% of the shares, the rest being in the possession of shareholders – individuals and institutions, such TFI AIG, ING, PKO and Millennium[2].

Case Facts:
• Vistula & Wólczanka had a greater financial potential in the acquisition

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[1] http://www.topmenedzer.pl/2008/08/case-study-bialy-kruk/ [06.2012]
[2] http://wiadomosci.gazeta.pl/Wiadomosci/1,80353,5217287.html [06.2012]
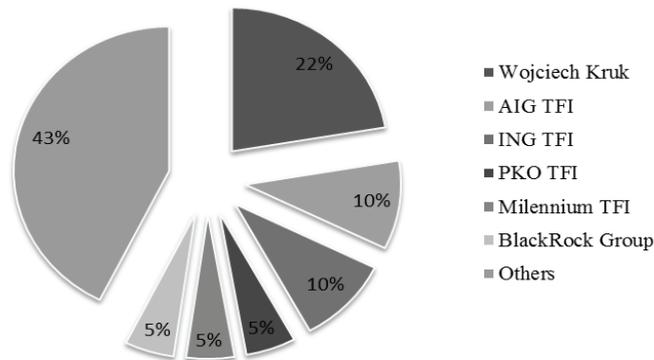
Fig. 1. Shareholder Group before taking over W. Kruk
Source: statistics taken from Gazeta Wyborcza

- Kruk was looking for ways to stop a hostile takeover, but came to the conclusion that the dispute would cost him too much
- His family had shares worth 150 mln zł
- In order to maintain his presidential position, he needed to take out a big loan
- Kruk sold a part of the family shares to Vistula & Wólczanka. At this point, the clothing co. was confident the takeover was successful
- This situation developed a huge threat to George Mazgaja, owner of the Alma Network and the Paradise Group, a leading group of boutique shops. Therefore, the concerned businessman slowly began buying shares of Vistula & Wólczanka
- Mazgaj had to be disclosed under the law after crossing the threshold of 5%
- After disclosing his identity and motives, J.W. Kruk and Mazgaj entered into an alliance in order to benefit each other and prevent Vistula & Wólczanka from an acquisition which could potentially control their market. Kruk purchased 5% of Vistula stocks and Alma purchased 6% (Figure .2.). Along with the support of PZU (one of the largest insurance companies in Poland), who owned 20% of Kruk's shares, they had enough power in their collaborate share ownership to remove the ally of Bauer – Maciej Wendzela, the head of Supernova Capital, who sits on the board of Vistula & Wólczanka.
- The next step was to change the chairman of the board to the previous president of Vistula & Wólczanka; Michal Wojcik.
- Although it seemed Kruk was defenseless, the hostile takeover failed[3].

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[3] http://www.topmenedzer.pl/2008/08/case-study-bialy-kruk/ [06.2012]

a)
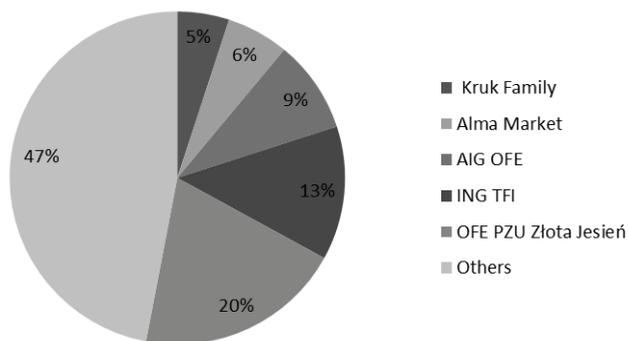
b)
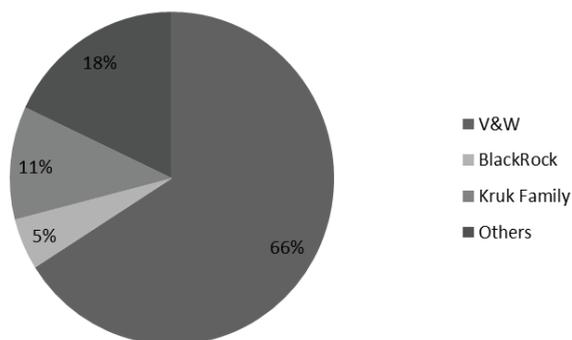
Fig. 2. a) The shareholding structure of Vistula & Wólczanka;
b) The shareholding structure after the acquisition of Kruk
Source: chart based on facts provide on notoria service

THE DESCRIPTION OF THE DEFENSE

The Defense of Kruk was much more difficult due to lack of majority shareholder ownership. Therefore, in spite of strong resistance from the jeweler and attempt to convince shareholders, these measures did not produce results such as in case of the takeover of Mannesmann.

The key factor in this acquisition case is the background of the counter-offer. Kruk did not disclose his motives to form an acquisition, but instead disguised his intentions jointly with other investors. His shareholders purchased large sums of shares in Vistula & Wólczanka. This small deviation from a typical counter-offer had a huge impact. If Kruk had made a counter-offer, not its shareholders, the results would have been totally different[4].

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[4] http://ceo.cxo.pl/artykuly/59337/Wymierne.efekty.wrogiego.przejecia.html [06.2012]
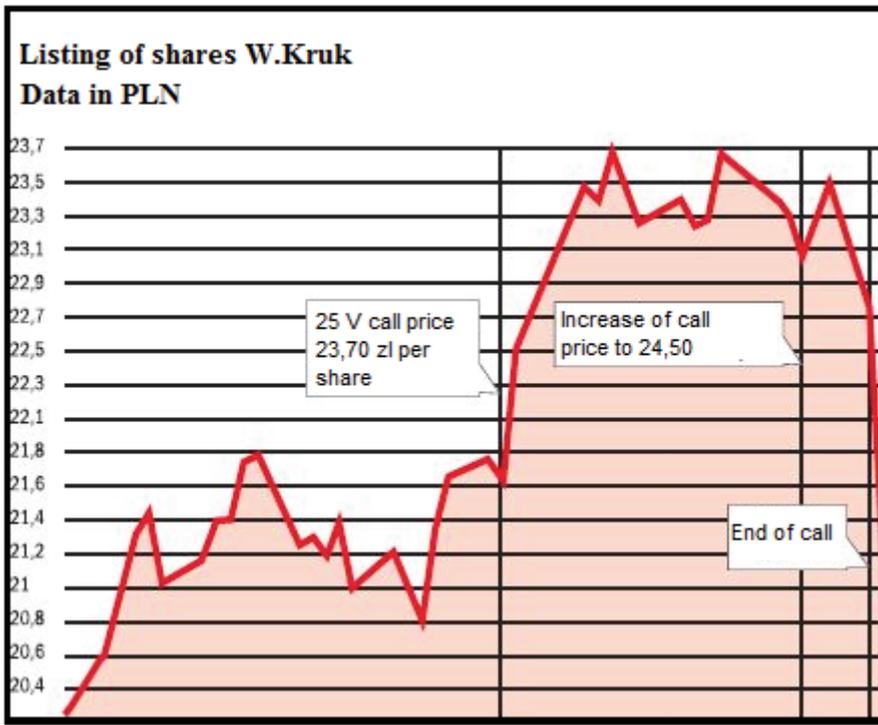
Fig. 3. Change in share prices Kruk during a hostile takeover
Source: http://wiadomosci.gazeta.pl

THE EFFECTS OF THE DEFENSE ACTIVITIES

The day before the tender offered to purchase shares of Kruk, Vistula & Wólczanka stock market capitalization amounted to 684 million zł and was 65% higher than Kruk, at that time of 414.5 million zł. During the call price of the shares, both companies remained relatively stable, which usually occurs in such situations, if there is no disclosure of any new circumstances of the transaction. In contrast, just after the close call, judgment by investors had changed, and since then, Vistula & Wólczanka share price fell by 43.5%. At the same time, until mid August 2008, the share price of Kruk fell 46.7% (see Figure 3.), therefore 2.2% lower than Vistula & Wólczanka. This difference observed during one trading session is minimal and therefore it appeared as if virtually nothing has happened. The drop of both of these companies shares was invisible as there were many other companies that also dropped during this session, although they dropped a bit more, it was insignificant. The WIG at this time dropped only 12.4%, three to four times less than the shares of the Kruk and Vistula & Wólczanka. Interestingly, although the Kruk shares substantially dropped,

their quarterly results showed positive profits unlike the Vistula & Wólczanka, which in this period recorded a loss.

The market valuation of Vistula & Wólczanka after the acquisition of Kruk had fallen dramatically, even including the acquired company, its value was less than before the acquisition. However, its market capitalization compared to Kruk relatively got stuck and was 10% higher than it was before the transaction. It is worth pointing out however, that the amount investors paid, nearly 300 million zł in Vistula & Wólczanka was no longer there due to the stock devaluation, although the 300 M zl were financed from a loan. This translated directly into devaluation of the clothing company after the acquisition. The value of Kruk also declined, but as a rule, most of the value created by the merger goes to the seller, therefore Kruk still profited from the deal. What's more, the price obtained for shares in the event of a hostile takeover is on average 15% higher than in the case of a friendly takeover. Therefore during a disputed bid, one way or another, gives better results for deciding to finally sell the shares. But it turns out that sometimes the premium may be much greater[5].

2. THE ATTACK OF NEW WORLD RESOURCES ON BOGATYNKA

THE HISTORY OF THE ACQUISITION

At the end of October 2010, the Czech coal producer, New World Resources (NWR), announced the call for entries for sale of shares of a leading Polish hard coal mine company, called "Lubelski Węgiel Bogdanka". This was the largest in the history of the Warsaw Stock Exchange hostile takeover attempt. This intention from the Czech company qualified as an ideal goal, as they had dispersed shareholders, over 50% of their shares were in pension and investment fund portfolios (Figure 4.), as well a small share was owned by the State. This diverse balance of shareholders gave them the potential for easier negotiations during a majority stake, but one major shareholder was still needed to negotiate the price[6].

NWR announced that he wants to focus 100 percent on the Bogdanka shares; he wanted to withdraw it from the stock exchange, and combine it as a subsidiary with its new headquarters in London. In order to accomplish this aim, he wanted to spend 3.4 billion zł[7],, and the offer was addressed to shareholders and was neither discussed nor consulted with the Polish company. He offered Bogdanka's shareholders a price of

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[5] http://ceo.cxo.pl/artykuly/59337/Wymierne.efekty.wrogiego.przejecia.html [06.2012]

[6] http://www.cire.pl/item,51842,14,0,0,0,0,0,proba-wrogiego-przejecia-bogdanki-przez-NWR-przykladowe-srodki-zapobiegawcze-i-mozliwosci-obrony.html [06.2012]

[7] http://wyborcza.biz/biznes/1,101562,8528359,Zwiazki_w_Bogdance_mowia_Bakali_stanowcze__nie.html [06.2012]

100.75 zł per share. This gave a 13 percent premium over the last valuation prior to the call of 89.05 zł. Crucial to the plan was to persuade the open pension funds Aviva OFE, OFE and OFE PZU Złota Jesień[8] ING to answer the call. For this purpose, the same group president of the Czech Zdenek Bakala, went to the Polish capital. Ultimately, the merger of both companies had to create a leading coal mining industry in Central Europe. Bogdanka would be a platform for further acquisitions in the region[9]. However, thanks to the determined opposition of the Polish company's top management, support from trade unionists, politicians and the public, subscription ended in complete disaster, and the invaders withdrew from the investment.
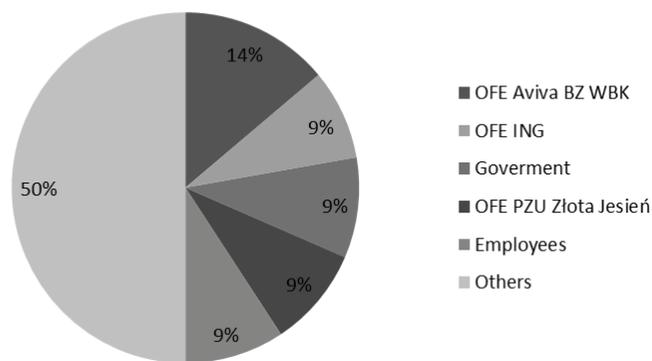
Figure 4.: Shareholding Company in Lublin Coal Bogdanka
Own work based on: Gazeta Wyborcza

THE DESCRIPTION OF THE DEFENSE

Czech investors advised that the call will take place only if they could guarantee 75 percent of the Bogdanka shares. Theoretically, the best way to stop the takeover was for Bogdanka to discourage their shareholders to sell their shares. Top management of Bogdanka decisively opposed to the call intentions of the NWR (required by the rules governing the call), as this call showed no interest on the company or its strategic plans. The written proposal of the price offered by NWR was grossly below fair value of the Bogdanka shares. It did not include, in particular, the effects of an investment program for the company such as the premium for control, long-term business prospects and it did not give any technological or organizational benefits. Bogdanka

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[8] http://wyborcza.biz/biznes/1,100969,8712584,Akcjonariusze_NWR_zgodzili_sie_na_przejecie_Bogdanki.html [06.2012]
[9] http://wyborcza.biz/biznes/1,100969,8712584,Akcjonariusze_NWR_zgodzili_sie_na_przejecie_Bogdanki.html [06.2012]

also pointed out that only the Czech investor held the benefits of the proposed transaction for the NWR group, except for those that could potentially arise as a result of its acquisitions, including the possible synergies. Experts in the industry confirm that NWR did not have much to offer Bogdanka and therefore the direction of transmission benefits were to be received only by NWR. The board of Bogdanka passed a report during the call, which further reinforced the detailed information published by the company that this call did not benefit their strategic plans and their future projected results.10 Moreover, the defense was supported by the trade unions, which identified this action as a hostile takeover and immediately brought together the Board, the Supervisory Board and shareholders to deal with this matter.11 It is worth noting that 10% of the shareholders were the employees who had strongly opposed the selling of the shares and therefore created a challenge for NWR to achieve his request of a 75% share. To further support this opposition, there was a statutory two-year law banning the employees from selling their shares and it was in force until December 2011[12]. Now the total package of shareholders declared "no" was up to 28 percent.

In addition, Bogdanka had to deal with a major media campaign which was controlled by NWR. During this call period, the Czech-Polish Investment Forum on Energy was held at the Warsaw Stock Exchange, and was attended by representatives of Polish and Czech government, and, perhaps not coincidentally, Mark Jelinek and John Fabian, the Vice Presidents of NWR. Nevertheless, Bogdanka emerged from this battle victoriously, as it was strongly supported by its employees, as well as politicians interested in the fate of their company[13].

THE RESULTS OF THE DEFENSE ACTIVITIES

Finally, the defense was successful. NWR resigned because of the lack of response to the call and their request of 75% shares dropped to a threshold of less than 50 percent shares[14].

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[10] http://www.cire.pl/item,51842,14,0,0,0,0,0,0,proba-wrogiego-przejecia-bogdanki-przez-NWR--przykladowe-srodki-zapobiegawcze-i-mozliwosci-obrony.html [06.2012]

[11] http://forsal.pl/artykuly/460078,przejecie_bogdanki_przez_NWR_zarzad_i_zwiazki_zawodowe_sa_przeciw.html [06.2012]

[12] http://wyborcza.biz/gieldy/1,101589,8742004,Zdenek_Bakala_dostal_kosza_od_akcjonariuszy_Bogdanki.htm [06.2012]

[13] http://www.cire.pl/item,51842,14,0,0,0,0,0,0,proba-wrogiego-przejecia-bogdanki-przez-NWR-przykladowe-srodki-zapobiegawcze-i-mozliwosci-obrony.html [04.2011]

[14] http://biznes.interia.pl/gieldy/aktualnosci/news/bogdanka-sie-tanio-nie-sprzeda,1563799,1844 [04.2011]

3. CONCLUSIONS AND RECOMMENDATIONS FOR MANAGERS OPERATING IN THE POLISH STOCK MARKET

The global economy is expanding at full force and thus leaves opportunity for both friendly and hostile mergers and acquisitions. The managers involved in a merger or acquisition offer where the conditions are not favorable or where there is a call directed to the shareholders, could prepare a defense strategy that would protect their independence. Studies demonstrate that when a company is planning their defense tactics, their aims result in achieving a higher price. However, if the strategy is to reject the offer, the company must make sure that they have adequate support, which will ensure that shareholders do not answer the call. It is crucial to pay attention to the trade unions, as quite often they draw attention of the media, politicians and investors. This often creates a nationwide debate and involves high-ranking officials, as was the case in the acquisition of BIG Bank Gdansk by Deutsche Bank which drew attention directly with the President himself, Kwaśniewski Aleksander. Additional support may also be a "poison pill," and any other statutory or regulatory provisions, such as:
* Restrictions on the maximum number of votes at a general meeting;
* A minimum threshold number of shares, allowing for a change in management
* Beneficial anti-takeover law

It is important whether or not the owners have at least 50% of the shares, or a golden share, otherwise the defense could be significantly impeded. Acquiring a controlling stake, as experience shows, does not necessarily mean having half of the shares. If the shareholders are fragmented, and the main shareholders are mutual funds, you may find (as in the case of V & W), that even 5% is sufficient to maintain control. However, if the acquisition can no longer resist the inevitable or is very difficult to resist, it is possible to utilize the "white knight" which is the preferred investor who on favorable terms will merge with the company. In most cases, the white knights themselves ultimately do not protect companies from a takeover, but with their assistance, they were capable of attaining better financial terms which were more favorable to the board and even in certain circumstances, they converted a hostile acquisition into a friendly acquisition.

The following are preventative and active measures which can assist companies operating in the Polish market in order to provide guidance in developing their defense strategy implementation:

Preventive Measures
* Implement the "poison pill"; the statutory provisions that limit the ability to change the board and make it more difficult to obtain a majority vote at a general meeting, at the same time reduce the company's attractiveness as a target in the eyes of potential buyers.

• Introduce a 'golden share', which will give an effect to the strategic decisions of the company even in the absence of a controlling interest

• Pay attention to stock dilution and selling shares at the same time to attempt to maintain a controlling interest

• Maintain good relations with employees, trade unions, in order to engage in local initiatives. Practice shows that this type of relationship building can later obtain public support

• When a company is international, they should consider the possibility of re-locating their headquarters to a country with a stronger anti-takeover law

Active Measures

• Maintain your position in opposition by sticking to a "just no" throughout the negotiation process, simultaneously keeping this strong "just no" even in controversy in the public eye and during anti-takeover arguments addressed to the shareholders. The experiences of Polish and foreign companies have shown that the resistance during the bid, increases the final offer, while in the case of a good line of argument (eg, a threat to jobs, lack of cost effectiveness of the process, etc..) allows for the support and involvement of the public and politicians

• Search for a white knight, although in practice it is quite difficult, but the mere fact often influences the invaders offer, at the same time offers the potential for an alternative connection

• Consider a counter-offer as a good option when the attacker is a company of similar size and/or its stock value drops significantly during the attack (due to e.g. lack of support or debt created for the purpose of the goal), it has dispersed shareholders, and it is possible to get a control package or change its top management

The knowledge gained from this literature and an analysis of the experiences of other companies can significantly help in the planning of potential actions, and also appear to be crucial in the events of an actual defense. Note, however, that friendly and hostile takeovers are dynamic processes, in which each case should be considered separately and simultaneously. It is vital to adjust the appropriate actions to specific movements made by those that pose offers in order to maintain control in the defense strategy. Therefore, even very well protected and prosperous companies, despite fierce defense actions, may still become the victim of a hostile takeover.

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HURST DEPENDENT INDEX COMPOSITION BASED ON WIG-BANKI

Authors proposed a new way to calculate one of the stock exchange indices. The research was conducted on the Warsaw Stock Exchange. The model is based on a relation between analysed banks and an analysis of their behaviour. The results of the model was compared to the results of the index WIG-BANKI and two banks (PEKAO and PKOBP) with the largest percentage contribution in that index.

1. INTRODUCTION

On the world market there are a lot of industries, in which companies can attempt to achieve success. Sometimes it is hard to change from one to another, especially when the selected second industry is completely different from the first. A good example of this process is NOKIA, a company which start as wood processing plant and now is one of the biggest and the most recognized electronics company on the world[1].

The described transition – like NOKIA – is not seen too often on the market, but when it happens the changes are huge. On the other hand smaller changes in a company happen more often and are usually related more with adapting to the current market situation than an attempt to completely change its approach.

However, all such changes are associated with the financial sphere such as an acquisition of capital, business valuation or company assessment. All of those situation are connected in a greater or lesser degree to the stock exchange. To analyse those the

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impact on those areas one can monitor the stock exchange indices. The basic defini-
tion of a stock exchange index states that an index is a group of companies noted on
the stock exchange, which have a common feature like:

   − are in the same industry (WIG-BANKI, WIG-INFO),
   − are the biggest joint-stock company (WIG20).

Stock exchange indices are very useful during the analysis, since with their aid one
can observe how the changes on the stock exchange proceed. There is also a lot of
models and rates which use indices as one of their key parameters.

The biggest world indices are one of two types: capital or price weighted. To calcu-
late a price weighed index one simply sums the value of price changes ($p_k(t)$) and
divides them by the number (N) of analysed companies.

$$< INDEX > = \frac{1}{N} \sum_{k \in <INDEX>} p_k(t) \tag{1}$$

Indices calculated this way include Dow Jones Industrial Average (DJIA), Nikkei
Heikin Kabuka (NIKKEI 225) or Polish WIG20.

The second one, call capital weighed or income index. To calculate it one uses
share price, but also should take into account dividends and voting rights. The easiest
way to calculate this type of index is to sum the products of listed company shares
($l_k(t)$) and their prices ($p_k(t)$) regulated by the number of companies (N).

$$< INDEX > = \frac{1}{N} \sum_{k \in <INDEX>} l_k(t) p_k(t) \tag{2}$$

To the capital indices one can include the biggest world index i.e. Standard &
Poor's (S&P 500), Deutscher Aktienindex (DAX), Cotation Assistee en Continu
(CAC40) or Financial Times Stock Exchange (FTSE100).

Because the main component of those methods is price it can be said that stocks
with the biggest price have the greatest impact on the index. That is why the authors
propose a new way of calculating indices with the help of relations between individual
companies.

2. MODEL DESCRIPTION

During the research for this paper authors analyse WIG-BANKI index, which is composed of 14 banks. The research was conducted on a set of data from 01.06.2011 to 01.06.2012. Since the index constituents changed several times, there are a few companies which weren't noted earlier, therefore one analyses only 11 banks which were noted during the whole period. This group is composed of [5]:

BANKBPH,	KREDYTB,
BOS,	MILLENNIUM,
BRE,	PEKAO,
GETIN,	PKOBP,
HANDLOWY,	UNICREDIT.
INGBSK,	

To show a new way to calculate an index this model used two methods, which are connected not only with stock price but also with the behaviour and relations between companies. Using the first method one can analyse the relationship between banks, while the second one analyses the price signal for every company and shows the possible future character of the changes.

2.1. DISTANCE MATRIX

Minimal Spanning Tree is the simple method, which can show the often invisible relationships between observed companies. The easiest way to obtain MST values is to calculate a correlation coefficient for all pairs of companies and with its help create a correlation matrix [3].

$$C_{\alpha\beta} = \frac{\sum_{i=1}^{N}(\alpha_i - \overline{\alpha})(\beta_i - \overline{\beta})}{\sqrt{\sum_{i=1}^{N}(\alpha_i - \overline{\alpha})^2(\beta_i - \overline{\beta})^2}} \quad (3)$$

The correlation coefficient can take values between (–1) and 1. If the value is close to (–1) one can say that the pair of analysed series is anti-correlated and it means that their behaviour will be opposite to each other. The reverse situation can be observed when the value is close to 1, which means that their behaviour is similar. A correlation coefficient close to 0 means that no linear correlation between the

analysed pair of items exist and it can be said that their behaviour is independent from each other.

When the matrix of correlation coefficients is created, one can calculate the distance between every pair of the analysed date set. The equation (2), allows to calculate the distance ($d_{\alpha\beta}$) between a pair of items using only the correlation coefficient ($C_{\alpha\beta}$).

$$d_{\alpha\beta} = \sqrt{1 - C_{\alpha\beta}^2} \qquad\qquad (4)$$

As one can see, such distance can take values between 0 and 1. It means that when the correlation coefficient is close to value 1 or (–1) then the distance between that pair practically doesn't exist – it's close to 0. The value of distance equal to 1 mean that the correlation between that pair of elements doesn't exist.
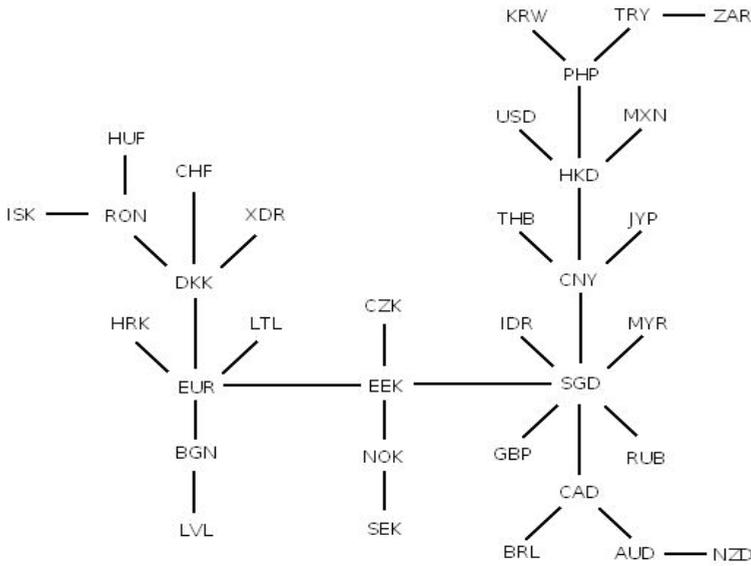

Fig. 1. MST graph or world currencies [3]

The next step of MST is to create a graph of the relations between companies. To create this graph one should connect items, which have the smallest value of correlation coefficient. That's why one can started with create a list of paired items with the smallest values. Having this list one connects items starting from the lowest values. However it's should be remember that when one element is used in graph it can't be used again (nodes of a graph cannot be repeated). This means that loops can't exist in a MST graph.

2.1. HURST EXPONENT

The next parameter, which will be used during this analysis is the Hurst exponent – often noted as H. This parameter can be calculated from one of several methods, for example: Detrending Moving Average (DMA), Detrending Fluctuation Analysis (DFA) or R\S method. In this paper authors decided to use the first one [4]. This method starts with calculating a moving average $\widetilde{y}_n(i)$ of length n :

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

where:
   $y(i)$ – time series,
   N – length of time series $y(i)$.
   Next stage it to calculate a detrended standard deviation:

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

The last step is to find a relation between standard deviation and Hurst exponent for the greatest possible range of n.

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

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. For a value H equal to 0.5 the signal is random and one can say that it's more like a Brownian motion. 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).

3. ANALYSIS OF RESULTS

To begin the creation a new index one starts with analysing the distance between all pairs of banks. As it can be seen in table 1, the smallest distance is between

PEKAO and PKOBP, which mean that those two companies are very strong dependent from each other. Also in the next three positions of the list one can always see PKOBP or PEKAO (two the biggest banks in Poland) with close distance to the several other banks. It should be also noted that the last two pairs have distance close to 1, which mean that correlation coefficient between them is oscillates around 0. This information shows that BRE and UNICREDIT are companies which aren't related with other analysed banks. Looking at the correlation coefficient for those two banks one can see that the highest values of correlation are between 0.16 and 0.08 respectively.

Table 1. Distances for WIG-BANKI companies
(Source: own work)

Companies	Distance
PEKAO – PKOBP	0,697
PEKAO – BRE	0,787
PKOBP – BANKBPH	0,840
PKOBP – HANDLOWY	0,856
BRE – MILLENNIUM	0,862
INGBSK – BRE	0,867
PKOBP – GETIN	0,891
KREDYB – BRE	0,903
MILLENNIUM – BOS	0,986
UNICREDIT – GETIN	0,997

The relationships between banks, which were analysed, are presented in Fig. 2. As it can be seen the central position, joining other banks, is occupied PEKAO and PKOBP. It should be noted that there are no large clusters and only two banks have a significant amount of neighbours: PKOBP and BRE (four connections).
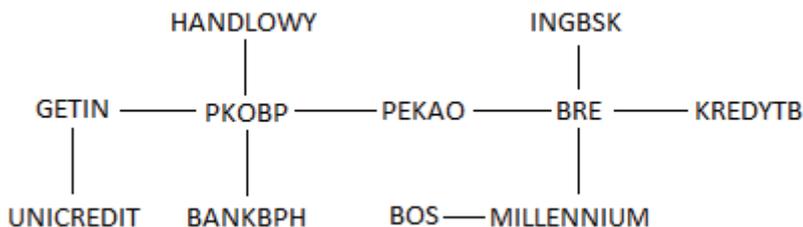

Fig. 2. MST for the WIG-BANKI (Source: own work)

The next step is to analyse the Hurst exponent value. As it can be seen from table 2, there only four banks which have a persistent signal (BANKBPH, BRE, GETIN, KREDYTB). This information indicates that only those companies have a greater

probability to maintain their trend then to change it. The rest of the analysed companies has H below 0.5, which indicates that the prices will fluctuate with higher probability (anti-persistence).

Table 2. Value of Hurst exponent for
WIG-BANKI companies
(Source: own work)

Company	H
BANKBPH	0.616
BOS	0.369
BRE	0.563
GETIN	0.563
HANDLOWY	0.490
INGBSK	0.438
KREDYTB	0.622
MILLENNIUM	0.423
PEKAO	0.395
PKOBP	0.475
UNICREDIT	0.441

With the above information at hand one can proceed to calculate a new index. To calculate the contribution percentages authors use both calculated parameters (Hurst exponent and distance) as show below:

$$P_i = \frac{a}{N} H_i \sum_{j=1}^{N} d_{ij}$$

(8)

where:
P_i – percentage contribution of the *i*-th assets,
N – number of analysed banks,
H_i – Hurst exponent of the *i*-th assets,
d_{ij} – distance between *i*-th and *j*-th assets,
a – normalizing parameter.

During calculation of equation 8, one can see that the normalizing parameter value *a* for banks is equal to 0.45. The new percentage contributions are presented alongside the WIG-BANKI percentage contributions values in table 3. One can see that the contributions of the new index are spread more evenly then in WIG-BANKI.

However, it should be noted that the banks with the smallest distance (PKOBP and PEKAO) have the biggest percentage contribution in the real index. It might not be beneficial to take only those two banks for approximately 70% of the index.

Table 3. Percentage composition of WIG-BANKI
and the new index. (Source: own work)

Company	% new	% real
BANKBPH	11,17	0,67
BOS	7,62	0,15
BRE	9,98	7,59
GETIN	10,67	1,12
HANDLOWY	9,14	5,32
INGBSK	8,22	5,16
KREDYTB	11,49	1,45
MILLENNIUM	8,09	3,00
PEKAO	7,20	30,89
PKOBP	8,30	39,65
UNICREDIT	8,13	0,19

Percentage composition of the index obtained from the earlier analysis more evenly distributed as even small changes of the major banks from real index (PEKAO and PKOBP) do not result in large changes of the new index value. The greatest contribution to proposed comes from the banks with the biggest values of the Hurst exponent, which favours the stable companies (KREDYTB, BANKBPH, GETIN).
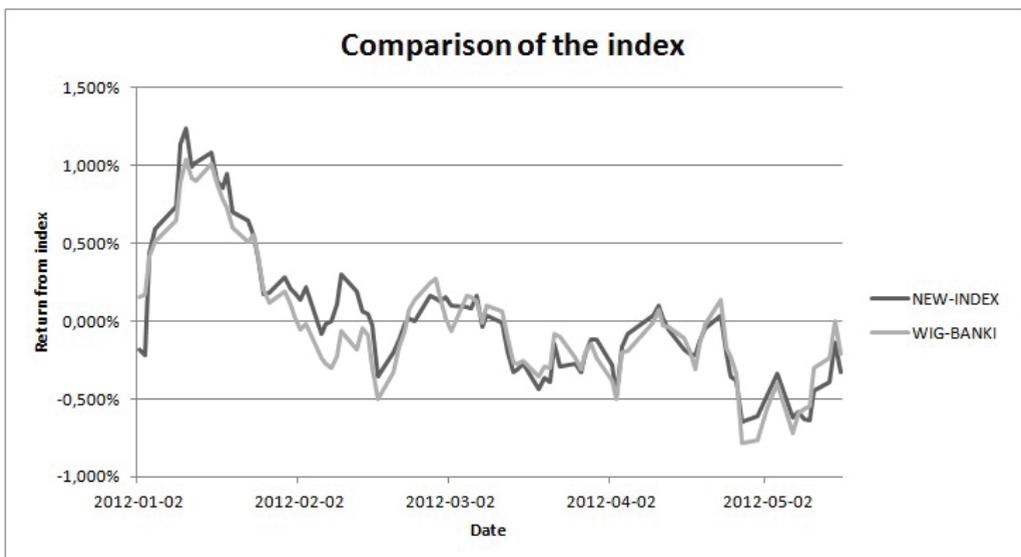

Fig. 3. Comparison of the moving average of returns from index WIG-BANKI
and NEW-INDEX. (Source: own work)

To show how the proposed index will behave one can analyse a moving average of returns for NEW-INDEX(proposed) and WIG-BANKI between 01.01.2012 and 01.06.2012. One can note that both index are quite similar. However NEW-INDEX seems to be more stable, which is the result of the new percentage composition.
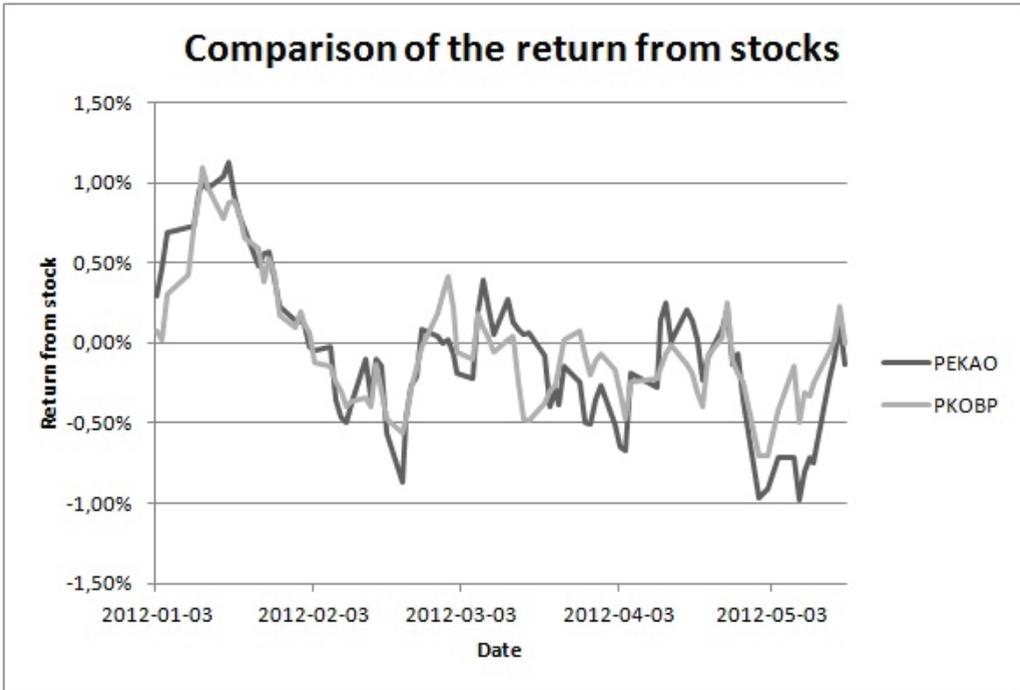

Fig. 4. Comparison of PEKAO and PKOBP moving averages of returns.
(Source: own work)

Analysis of the returns moving averages from PEKAO and PKOBP shows that those two banks have similar behaviour, which may have negative impact for the index (highly correlated banks with significant percentage composition cloud the overall picture).

Table 4. Statistical data of WIG-BANKI and NEW-INDEX
for date from 01.01.2012 to 29.06.2012. (Source: own work)

	WIG-BANKI	**NEW-INDEX**	PEKAO	PKOBP
Mean	−0.011	**0.021**	−0.031	−0.013
Standard deviation	0.0040	**0.0043**	0.0048	0.0039

Looking at the mean from moving average for all of the analysed items (table 3) one can see, that NEW-INDEX obtained a positive value, despite the real index was negative. Standard deviation of NEW-INDEX is lower than the original one which may allow better prediction (higher stability of the index).

4. CONCLUSION

Stock exchange indices are parameters, which are used very often. That's why determination of an index in a standard way, which favours stocks which the biggest price, can be an erroneous approach. The best example is WIG-BANKI, which consists of PEKAO and PKOBP in 60%. Because of this composition it is very sensitive to the price changes of both banks.

Proposed model eliminated that sensitivity by introducing the new storages rates. Results obtained from the model, show that it's possible to get a more stable index that will reflect the behaviour of the entire sector. It can be especially helpful in a period of rapid changes when investors look at sector based indices for an indication for the entire stock exchange.

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Piotr NOWAK*, Maciej ROMANIUK**

ON PRICING FORMULA AND NUMERICAL ANALYSIS OF CATASTROPHE BOND WITH SOME PAYMENT FUNCTION

The increasing number and value of losses of natural catastrophes leads to problems with financial reserves for many insurers. The classical insurance mechanisms are not suitable for losses caused by natural catastrophes. Therefore new financial mechanisms like catastrophe bonds (in abbreviation cat bond) or options may be used to cope with consequences of natural disasters. The payment function of cat bond depends on some primary underlying asset, like interest rates and additional random variable, called *triggering point*. In our paper we apply the martingale method to price some catastrophe bond. Then we conduct Monte Carlo simulations to analyse influence of various parameters on the calculated price.

1. INTRODUCTION

The insurance industry face overwhelming risks caused by natural catastrophes, e.g. the losses from Hurricane Katrina in 2005 are estimated on 40–60 billion \$ (see [12]). Also other countries are affected by similar problems – e.g. Poland by extreme floods. The classical insurance mechanisms, i.e. application of central limit theorem, are not suitable for such extreme losses caused by natural catastrophes. Even one, single catastrophe could cause problems with reserves for many insurers or even bankruptcy of these enterprises. For example, after Hurricane Andrew more than 60 insurance companies became insolvent (see [12]).

The traditional insurance models (see e.g. [2, 5]) deal with independent risk with rather small claims, like car accidents. Contrary, the sources of losses from natural catastrophes are strongly dependent in terms of time and localization, e.g. single

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hurricane could blow out many houses, starts fire, leads to robberies, etc. Additionaly, the values of such losses may be extremely high. Therefore new types of financial and insurance instruments are necessary for insurance industry.

So called securization of losses (i.e. "packaging" the risks into tradable asset, like bond or derivative) may be helpful for insurers in dealing with results of extreme natural catastrophes (see e.g. [3, 6, 7, 9]). The catastrophe bonds (cat bonds, see [4, 15, 19]) are the most popular example of catastrophe-linked securities.

Our paper is a continuation of our previous results (see [14-18]) in Vaugirard's manner (see [20]) to catastrophe bond pricing. We assume no possibility of arbitrage, independence between catastrophe occurrence and behaviour of financial market and replicability of interest rate changes by financial instruments existing in the market. We price catastrophe bonds applying the Hull-White (extended Vasicek) model and the Ho-Lee (extended Merton) model of risk-free spot interest rate. We consider a piecewise-linear form of catastrophe bond payoff function. In section 3 we find an analytical valuation formula for cat bonds, using the martingale method of pricing. Then in section 4 we use numerical simulations to analyse the behaviour of the obtained pricing formula.

2. CATASTROPHE BONDS

Assumption of the classical insurance models are not completely valid in case of huge catastrophic events. Instead of independent risk with rather small claims, the dependency of catastrophic losses in terms of time and localization and enormous values of such losses are noticed. Therefore a single catastrophic event could cause the bankruptcy of the insurer or serious problems with coverage of losses (see [3, 9]).

Then applying new kinds of financial or insurance instruments may be profitable. One of possible solutions is to "package" risks (i.e. losses) caused by natural catastrophes into more classical forms of tradable financial assets, like bonds, options or other derivatives. The most popular catastrophe-linked security is the catastrophe bond. According to [11] the cat bond market in year 2003 hit a total issuance of $1.73 billion, a 42% increase from 2002's record of $1.22 billion. To the end of 2004 there were about 65 successful emissions of cat bonds.

The payment function of cat bond depends on special, additional random variable called *triggering point* (see [8, 13, 15, 16]) – occurrence or other properties of specified type of natural catastrophe change the structure of payments. Triggering point may be connected e.g. with occurrence of catastrophe, the issuer's actual losses (e.g. losses from flood), losses modeled by special software based on real parameters of catastrophe, insurance industry index, real parameters of catastrophe (e.g. magnitude of earthquake) or hybrid index related to modeled losses. Other parameters like region and time interval for catastrophic event are described in detail for catastrophe bond. The structure of payments for cat bonds depends also on interest rates.

For example, the A-1 bond issued by USAA in 1997 was connected with losses caused by hurricane on the east coast of USA between July 15, 1997 and December 31, 1997. If the value of losses had been more than $ 1 billion, the coupon of the bond would have been lost. The payment depended also on LIBOR.

3. CATASTROPHE BOND PRICING

In this section we introduce pricing formula for catastrophe bonds. We continue our earlier approach from [14–18]. We begin with notations and basic definitions concerning catastrophe bonds and their pricing. We define stochastic processes describing dynamics of the spot interest rate and aggregated catastrophe losses. We assume time horizon of the form $[0, T']$, where $T' > 0$. Date of maturity of a catastrophe bond T is not later than T', i.e. $T \leq T'$. We consider two probability measures: P and Q and we denote by E^P and E^Q the expectations with respect to them.

Let $(W_t)_{t \in [0,T']}$ be Brownian motion. It will be used to describe the behaviour of the risk-free interest rate. Let $(U_i)_{i=1}^{\infty}$ be a sequence of identically distributed random variables with bounded second moment. We treat U_i as value of losses during i-th catastrophic event. We define compound Poisson process by formula $\widetilde{N}_t = \sum_{i=1}^{N_t} U_i$, $t \in [0, T']$, where $(N_t)_{t \in [0,T']}$ is Poisson process with an intensity $\kappa > 0$. For each $t \in [0, T']$ the value of process N_t is equal to the number of catastrophic events till the moment t. For each $t \in [0, T']$ process $\widetilde{N}_t$ describes the aggregated catastrophe losses till the moment t.

All the above processes and random variables are defined on a filtered probability space $(\Omega, F, (F_t)_{t \in [0,T']}, P)$. Filtration $(F_t)_{t \in [0,T']}$ is given by formula

$$F_t = \sigma\left(F_t^0 \cup F_t^1\right), \quad F_t^0 = \sigma\left(W_s, s \leq t\right), F_t^1 = \sigma\left(\widetilde{N}_s, s \leq t\right), \quad t \in [0, T'].$$

We assume that $F_0 = \sigma\left(\{A \in F : P(A) = 0\}\right)$ and that $(W_t)_{t \in [0,T']}$, $(N_t)_{t \in [0,T']}$ and $(U_i)_{i=1}^{\infty}$ are independent. Then the probability space with filtration satisfies the standard assumptions (see [17]).

We denote by $(B_t)_{t \in [0,T']}$ banking account satisfying equation $dB_t = r_t B_t dt$, $B_0 = 1$ for a risk-free spot interest rate $r = (r_t)_{t \in [0,T']}$.

We assume that zero-coupon bonds are traded in the market. We denote by $B(t, T)$ the price at the time t of zero-coupon bond with maturity date $T \leq T'$ and with face value equal to 1. We price catastrophe bonds under the assumption of no possibility of

arbitrage in the market. We assume that the market price of risk for zero-coupon bonds $\lambda_u = \lambda, u \in [0,T']$, is constant.

We make two additional assumptions. We first assume that investors are neutral toward nature jump risk (Assumption 1). This assumption has practical confirmations in the market (see e.g. [1, 20]). Secondly (Assumption 2), we assume routinely that changes in interest rate r can be replicated by existing financial instruments (especially zero-coupon bonds).

We consider a catastrophe bond, with a piecewise linear payoff function. Let $n \geq 1$, $0 \leq K_0 < K_1 < ... < K_n$, and let $w_1,...,w_n \geq 0$ be a sequence of constants, for which

$$\sum_{i=1}^{n} w_i \leq 1.$$

Definition 1. *We denote by* $IB_p(T, Fv)$ *a catastrophe bond with face value* $Fv > 0$ *, the maturity and payoff date* T *and a payoff function of the form*

$$v_{IB_p(T,Fv)} = Fv\left[1 - \sum_{j=0}^{n-1} \frac{\widetilde{N}_T \wedge K_{j+1} - \widetilde{N}_T \wedge K_j}{K_{j+1} - K_j} w_{j+1}\right].$$

Catastrophe bond $IB_p(T, Fv)$ satisfies the following properties:

1. Payoff function is a piecewise linear function of losses $\widetilde{N}_T$.

2. If the catastrophe does not occur in the period $[0,T]$, i.e. $\widetilde{N}_T < K_0$, the bondholder is paid the face value Fv ;

3. If $\widetilde{N}_T \geq K_n$, then the bondholder receives the face value minus the sum of write-down coefficients in percentage $\sum_{i=1}^{n} w_i$.

4. If $K_j \leq \widetilde{N}_T \leq K_{j+1}, \ \ 0 \leq j \leq n-1$, the bondholder receives the payoff equal to

$$Fv\left[1 - \sum_{0 \leq i < j} w_{i+1} - \frac{\widetilde{N}_T \wedge K_{j+1} - \widetilde{N}_T \wedge K_j}{K_{j+1} - K_j} w_{j+1}\right]$$

Moreover, the payoff decreases linearly on interval $\left[K_j, K_{j+1}\right]$ as a function of $\widetilde{N}_T$ from value $Fv\left[1 - \sum_{0 \leq i < j} w_{i+1}\right]$ to value $Fv\left[1 - \sum_{0 \leq i \leq j} w_{i+1}\right]$.

Let $f^M(t,T)$ be the market instantaneous forward rate for maturity T at moment t. If $P^M(0,T)$ is the zero-bond curve, then $f^M(0,T) = -\dfrac{\partial \ln P^M(0,T)}{\partial T}$.

3.1. THE HULL–WHITE MODEL

We assume that the risk-free spot interest rate r is described by the Hull–White (extended Vasiek) model. The dynamics of r is given by the following stochastic equation

$$dr_t = \left(\vartheta(t) - ar_t\right)dt + \sigma dW_t \tag{1}$$

for a, $\sigma > 0$ and function ϑ exactly fitted the term structure of interest rates currently observed in the market, given by formula

$$\vartheta(t) = \frac{\partial f^M(0,t)}{\partial t} + af^M(0,t) + \frac{\sigma^2}{2a}(1 - e^{-2at}) + \lambda\sigma.$$

The following theorem, proved in [18], gives the pricing formula for catastrophe bonds in case of the Hull-White dynamics of the risk-free spot interest rate.

Theorem 1. *Let* $IB(0)$ *be the price of* $IB_p(T,Fv)$ *at time* 0. *Then*

$$IB(0) = P^M(0,T)\exp\left(\beta(0,T)f^M(0,0)\right)Fve^{-\beta(0,T)r_0}E^P v_{IB_p(T,Fv)}, \tag{2}$$

where

$$E^P v_{IB_p(T,Fv)} = Fv(1 - (1-\varphi_n)\sum_{j=1}^{n} w_j - $$

$$\sum_{m=0}^{n-1}\{(\varphi_{m+1} - \varphi_m)\sum_{0 \le j < m} w_{j+1} + \frac{e_m - (\varphi_{m+1} - \varphi_m)K_m}{K_{m+1} - K_m}w_{m+1}\}), \tag{3}$$

$\varphi_m = P(\widetilde{N}_T \le K_m)$, $m = 0,1,...,n$, $e_m = E\widetilde{N}_T I_{\{K_m < \widetilde{N}_T \le K_{m+1}\}}$, $m = 0,1,...,n-1$ and $\beta(0,T) = \dfrac{1}{a}(1 - e^{-aT})$.

3.2 THE HO–LEE MODEL

Let us assume that the dynamics of the risk-free spot interest rate r is described by the Ho-Lee (extended Merton) model. The stochastic equation for r has the form

$$dr_t = \vartheta(t)dt + \sigma dW_t \tag{4}$$

for $\sigma > 0$ and function ϑ exactly fitted the term structure of interest rates currently observed in the market, given by formula $\vartheta(t) = \dfrac{\partial f^M(0,t)}{\partial t} + \sigma^2 t + \lambda\sigma.$

Theorem 2. *Let $IB(0)$ be the price of $IB_p(T,Fv)$ at time 0. Then*

$$IB(0) = P^M(0,T)\exp(Tf^M(0,0) - Tr_0)FvE^P v_{IB_p(T,Fv)}, \tag{5}$$

where $E^P v_{IB_p(T,Fv)}$ has the form (3).

Proof. Using the above assumptions, we obtain the unique probability measure Q in similar way as in [20]. The following Radon-Nikodym derivative defines Q:

$$\frac{dQ}{dP} = \exp\left(-\int_0^T \lambda_u dW_u - \frac{1}{2}\int_0^T \lambda_u^2 du\right) \quad P - a.s.$$

For Q the family $B(t,T)$, $t \le T \le T'$, of zero-coupon bond prices with respect to r is arbitrage-free (see [17]). Zero-coupon bond can be priced by using of the following formula: $B(t,T) = E^Q\left(e^{-\int_t^T r_u du} \mid F_t\right)$, $t \in [0,T']$. Using arguments similar as in [20], we obtain the analogous equality for the catastrophe bond:

$$IB(t) = E^Q\left(e^{-\int_t^T r_u du} v_{IB_p(T,Fv)} \mid F_t\right). \tag{6}$$

From Assumption 1, $\exp\left(-\int_t^T r_u du\right)$ and $v_{IB_p(T,Fv)}$ are independent under Q. Therefore formula (6) for $t = 0$ can be written as the product $IB(0) = E^Q\left(e^{-\int_0^T r_u du}\right)E^Q\left(v_{IB_p(T,Fv)}\right)$

From the same assumption it follows that

$$E^Q\left(v_{IB_p(T,Fv)}\right) = E^P\left(v_{IB_p(T,Fv)}\frac{dQ}{dP}\right) = E^P\left(v_{IB_p(T,Fv)}\right)E^P\left(\frac{dQ}{dP}\right) = E^P\left(v_{IB_p(T,Fv)}\right)$$

Formula (3) follows from [17], Lemma 1. From zero-coupon bond pricing formula for the Ho-Lee interest rate model (see e.g. [10]) it follows that

$$E^Q\left(e^{-\int_t^T r_u du} \mid F_t\right) = \frac{P^M(0,T)}{P^M(0,t)}\exp\left((T-t)f^M(0,t) - \frac{\sigma^2 t(T-t)^2}{2} - (T-t)r_t\right)$$

Applying the above formulas for $t = 0$ we obtain (5).   □

4. MONTE CARLO EXPERIMENTS

We analyze cat bond prices in case of piecewise linear function and the Hull-White (abbreviated further as HW) model (see Section 3.1).

We start from obtaining prices as the function of shape parameter α and scale parameter β for Gamma distribution. HW model with parameters $a=0.025$, $\sigma=0.01$, $r(0) = 0.05$ is assumed in order to minimize the influence of interest rates on behavior of cat bond prices. The face value of the bond is set to 1, triggering points are given by $K_0 = 10$, $K_1 = 30$, $K_2 = 60$ and $w_1 = 0.3$, $w_2 = 0.2$. The graph of the bond price as the function of shape parameter α and scale parameter β may be found at Figure 1. Taking into account only one variable and the other set to constant, appropriate cut of the graph is hyperbolic-like function.
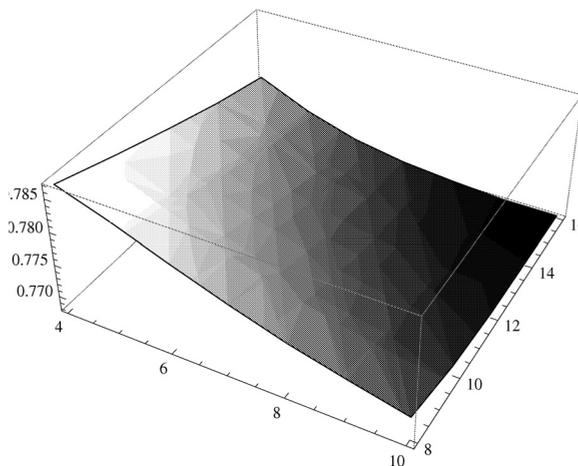

Fig. 1. Price of the catastrophe bond as the function of scale and shape parameters

In next case we analyze the cat bond price as the function of initial rate $r(0)$. The value of each loss is modeled by Gamma distribution with $\alpha = 5$ and $\beta = 10$. The other parameters are the same as in previous experiment. The graph of the bond price as the function of $r(0)$ may be found at Figure 2. As we could see this graph is almost linear function. The values of prices and relative percentage changes in prices may be found in Table 1. As we could see these changes have rather high values.
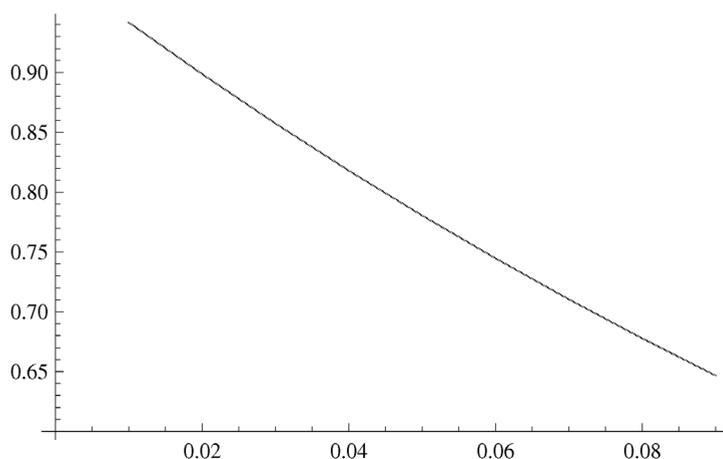

Fig. 2. Price of the catastrophe bond as the function of initial rate

Table 1. Price of the catastrophe bond as the function of initial rate

$r(0)$	0.01	0.02	0.03	0.04
Price	0.941772	0.898641	0.857306	0.817905
Change (%)	0	−4.57977	−4.59972	−4.59591

$r(0)$	0.05	0.06	0.07	0.08	0.09
Price	0.780439	0.744684	0.710388	0.677786	0.646665
Change (%)	−4.58073	−4.5814	−4.60544	−4.58932	−4.59157

We also analyze the influence of type of distribution on cat bond price. Therefore we find prices for two types of distributions which describe value of each loss: Gamma distribution and Weibull distribution (see Figure 3, cat bond prices for Gamma distribution are denoted by circles, for Weibull distribution – by squares). In each experiment we use the same expected value and variance for these distributions (see Table 2 for appropriate sets and prices). However the differences in prices are rather small.

5. CONCLUDING REMARKS

In this chapter we use approach based on neutral martingale method and Monte Carlo simulations in order to price and analyse some features of example of catastrophe bond. We price the cat bond applying the Hull–White model and the Ho–Lee model of the risk-free spot interest rate. Then we use simulations to analyse the behaviour of the obtained pricing formula in series of numerical experiments.
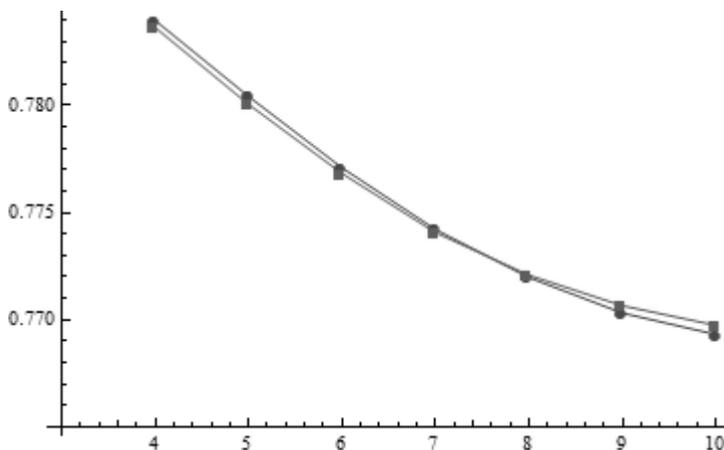

Fig. 3. Price of the bond for Gamma and Weibull distribution
describing value of each loss (X axis – set number in Table 2)

Table 2. Price of the bond for Gamma and Weibull distribution describing value of loss

Set number	4	5	6	7
Expected value	40	50	60	70
Variance	400	500	600	700
Price (Gamma)	0.783963	0.78042	0.777083	0.774207
Price (Weibull)	0.783636	0.780046	0.77682	0.774069
Difference	0.000327	0.000374	0.000263	0.000138

Set number	8	9	10
Expected value	80	90	100
Variance	800	900	1000
Price (Gamma)	0.771968	0.770309	0.76931
Price (Weibull)	0.772076	0.770651	0.769738
Difference	–0.000108	–0.000342	–0.000428

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