FORECASTING THE EFFECTS OF INVESTMENTS IN KNOWLEDGE-WORKERS IN THE SME SECTOR, USING THE GMDH METHOD

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Abstract: The enterprises functioning in market economy have to implement changes in systems of organization and management that they use. In economy practice making a decision in enterprise is conditioned by competitors' action, changing factors of environments, e.g. technical progress and results of the research works. Added value for SME can be determine as knowledge, employees' skills and abilities, social relation, know-how, and particularly effective investing in intellectual capital. The enterprises which invest in knowledge and systems of work are achieved competitive advantage, because of their workers' readiness to learning and qualifying themselves and also thanks to effective information and communication transfers. In this paper we allowed to respond to the following question: whether a given algorithm that enables the characteristics of the knowledge-workers and the expected results of expenditures on the intellectual capital (potential benefits from investing in the knowledge-workers) binding? This paper presents prediction effects of investments in knowledge-workers in the SME sector when using the neural systems GMDH basing on the Ivachnienko algorithm.

Key words: Intellectual capital in SME, GMDH method, investing in intellectual capital.

1. Introduction

Currently, the advantage of a company in the SME sector is determined by effectiveness and the extent of the knowledge-workers' involvement. The role of human capital management consists in striving to increase the share of immaterial resources (at the costs of the material ones) in the generated products, services, and the total market value of an organization [10]. It is an important part of the intellectual capital of an organization, as it influences the development of its other elements, i.e.: the structural capital and the customers' capital [2]. The subject literature includes various definitions of the intellectual capital. „Intellectual capital means the possessed knowledge, experience, organizational technology, relations with customers, and professional skills which provide [...] competitive advantage on the market" [5]. "It is a knowledge which can be turned into value" [8].

Building the company's intellectual capital, the employees must cooperate in creation of the company's value. In this context, the employees should be convinced that they work in a strategic partnership and generate benefits in the company. Such employees are distinguished by specific traits (intelligence, involvement, energy, positive attitude, reliability, honesty), ability to learn (receptivity of the mind, imagination, analytical thinking), and motivation for sharing the information and knowledge [15].

On the basis of the definitions, it can be assumed that a knowledge-worker is distinguished by:

- creativity (C),
- knowledge (K),
- qualifications (Q),
- reliability (R),
- skills (S),
- involvement (I),
- honesty (H).

In the SME sector, the knowledge-employees can be evaluated according to the aforementioned characteristics:

$$Kw = \{C, K, Q, R, S, I, H\} = \{C = 1,\ldots, n; K = 1,\ldots, 5; Q = 1,\ldots, 5; R = 1,\ldots, n; S = 1,\ldots, p; I = 1,\ldots, n; H = 1,\ldots, p\},$$

where each trait of an employee is precisely defined, and has an ascribed value:

- C – creativity – ability to generate new, innovative ideas (index: number of ideas (new solutions, created by the employee during a year),
- K – knowledge – proper processing and usage of information (index: results of a specialist test of the given employee, the test is constructed depending on the employee's profile, graded 1 to 5: 1-poor result, 5-the best result),
- Q – qualifications - education and professional experience (index: graduating from studies, postgraduate education, courses, trainings – secondary education: 1, higher education: 2, additional specialist courses: 3, post-graduate studies: 4, MBA studies: 5),
- R – reliability – preciseness of the completed tasks (index: number of complaints from the customers during a year,
- S – skills – quality the completed tasks (index: work productivity),
- I – involvement – creating productive relations in a company (index: number of new customers gained during a year),
- H – honesty – completing tasks based on trust (index: number of employees' meetings in which the employee participated and given the new ideas to the number of all the meetings during a year).

For a company, investing in the knowledge-workers comes down to organizing trainings for the employees (the second chapter of this article presents the remaining factors of intellectual capital development). Treating the training as an investment results in expectations of reimbursement of the incurred expenditures in a specific time. Yet, assessing profitability of an investment in the intellectual capital requires the so-called soft categories, e.g. the company's organizational culture. A method, which on the one hand would allow for demonstration of relationship between the knowledge-workers' characteristics, and company's benefits, and on the other would allow for estimation of the potential results of expenditures incurred on the intellectual capital, is sought.

The following research thesis has been put forward: *There is a very specific relationship between the characteristics of the knowledge - workers, and the expected results of expenditures on the intellectual capital (potential benefits from investing in the knowledge-workers). In other words, investing in the intellectual capital is profitable, if the value of the potential benefits function B(Kw) is acceptable for the management of the SME sector company.*

Furthermore, the following research problem has been formulated: *Important potential benefits generated by the intellectual capital are distinguished in the SME sector company. Is there a method allowing to estimate the return on an investment in the intellectual capital, in the category of gaining the expected benefits?*

The second charter of the article presents a conception of knowledge-workers management in the SME. Factors influencing the development of the intellectual capital in the SME were defined, and the expected benefits from expenditures incurred on the intellectual capital were distinguished. Methods of evaluating profitability of investments in the intellectual capital, known from the subject literature, were demonstrated. The need of applying econometrical methods to solve the stated research problem was emphasized.

The third chapter contains characteristics of the GMDH as a method allowing to define the potential return on investment in the intellectual capital. Current examples of applying this method were presented.

The fourth charter presents the process of forecasting the return on investment in the intellectual capital, in the aspect of gaining expected benefits by the company management.

The summary presents directions of further works.

2. Managing intellectual capital in SMEs

The process of managing intellectual capital should consist of two stages: identifying and measuring. Literature distinguishes qualitative measures (e.g. Danish project of IC measurement, 'Scandia' navigator, intangible assets monitor, IC model – TM Rating, VCSTM, balanced result sheet, report by Saratoga Institute) and methods of valuating intellectual capital (e.g. MV/ MB, q-Tobin, CIV, KCE, VAICTM, economic added value, IAV model, Strassmann's method, IAMVTM, technology broker). Attempts are made continuously to find methods for measuring intellectual capital and still there is no one recognised method enabling to build an intellectual capital reporting system. The difficulty is that the majority of concepts are prepared for specific companies, in other words such measuring methods are tailor made and their general application is not possible. [4, 5, 7, 9 and 12].

Table 1. Analysis of methods of valuating intellectual capital
(source: self study on the basis of [4, 9, 15])

Methods of valuating intellectual capital	Advantages	Weakness
Ross's method - indicators in two classes: human capital, structural capital	Value of intellectual capital's indicators	Subjective choice of intellectual capital's indicators
Danish project of IC measurement - indicators in 4 classes: human capital, structural capital, organization technology, relations with clients	Dynamic matrix of intellectual capital's indicators	Insufficiently number of intellectual capital's indicators
Scandia navigator – measuring intellectual capital based on analysis of 5 areas: client, finance, processes, personnel, organization's development)	Monitoring of organization's productivity.	Subjective choice of intellectual capital's indicators.
IC – Rating^{TM} - measuring intellectual capital based on 4 areas: business policy, human capital, relation's capital	Intellectual capital as organization's added value	Subjective choice of intellectual capital's indicators.
Intangible assets monitor - intellectual capital's indicators in 3. areas: inner and external structure and competence. In the each area in 4. classes: increase, regeneration, productivity, stability.	Controlling in the area: intellectual capital	Subjective choice of intellectual capital indicators
Balance Scorecard – indicators in 4 areas: finance, client, inner's processes and learning process.	Logic matrix of intellectual capital indicators	static matrix of intellectual capital indicators
VCS^{TM} - indicators in 3 phases: design of new product, analysis of technological processes, initiation of product in the market.	Research of main enterprises information's needs.	External reports
Value discoverer – 3 stages: 1) identification of competence and of intangible assets; 2) valuating of weakness and advantages of intangible assets; 3) resource allocation.	Identifying of main competences.	Subjective choice of intellectual capital indicators.
Report by Saratoga Institute – indicators in the 6 area of intellectual capital: organization's productivity, human resource structure, salary, added welfare, dismissal, training	Matrix of a few area of managing intellectual capital.	Not for SMEs
MV/MB – relation between the market and account value, (if the relations is more than 1, that the intellectual capital exists.	Simply calculation	Over - simplification
Q – Tonbina - relation between market value and intangible assets value (if more than 1 and „q" competition enterprises, that the profit of intellectual capital exists.	Simply calculation	Over - simplification
CIV – value of „current prizes"	Simply calculation	Average value of indicators
VAIC^{TM} (KCE) – value of intellectual capital	Correlation between profit of intellectual capital and profit of organization's activity	Profit of material assets , finance assets and intangible assets

Methods of valuating intellectual capital	Advantages	Weakness
Economic added value	Correlation between profit of intellectual capital and profit of organization's activity	Complicated model
IAV – the organization's value based on innovation and business assets	Meaning of innovation and business assets in added value creating.	Profit of material assets , finance assets and intangible assets
Strassmann's method - knowledge's base (market value and cost of knowledge's capital)	Exact date's base	Over - simplification
IAMV^{TM} – definition of market value as the account and market value.	Indentifying of main intellectual capital's parameters	Subjective definition of the account and market value.
Technology broker – intellectual capital value is based on indicators in 4.classes: human capital, structural capital, organization technology, relations with clients .	Treating intellectual capital as product creating.	Qualities results

The following is a presentation of vices and virtues of the selected qualitative measures and methods of the intellectual capital evaluation, based on the subject literature [4, 9, 15], table 1.

As a result of the completed comparative analysis of the measurement models and evaluation of the intellectual capital (table 1), a need to create a method of forecasting the effects of investing in the company's employees was noticed. In the SME sector company, there is a database, containing precisely defined values of the knowledge-workers' traits, and the specific values of the expected SME benefits from investing in the human capital are defined. A solution allowing to make a strategic decision in a company, regarding investments in creation and development of the human capital, is sought. The following conception of analysing the profitability of a strategic decision in the personal function realization process was adapted.

Treating the deliberations on the profitability of strategic decisions in a company in the category of knowledge-workers development, and simultaneous gain of competitive advantage, the human capital development factors were defined (table 2).

Assuming, that specific expenditures on the knowledge-workers must be incurred, benefits (specific values of the determined indexes) from the outlays incurred in the company should be expected.

Benefits at the level of organization in the SME sector company were defined (on the basis of the subject literature and the author's own research).

- Return on Assets (ROA) - profit net / assets,
- Return on Equity (ROE) - profit net / equity,
- Return on Sales (ROS) - profit net / return,
- share working capital in assets - working capital/assets, where working capital = current assets - short-term liabilities,
- number of paten (license),
- number of innovative project.

Table 2. Knowledge-workers development factors, *(source: self study on the basis of [10])*

Knowledge-workers development factors	Detailed description
Trainings	Set of purposeful, systematic actions, aimed at extending and deepening of specific elements of the human capital, and at equipping it with new elements, useful now, or in the future, for the employees of a given company
Reorganization of competences	Extending the scope of decision-making and/or enriching the work content
Organizational culture	Set of values, models, and convictions which is perceived by the company employees
Balance between career and private life	Programmes supporting flexible working time (e.g. annual work settlement, compressed working week, dispersed work)

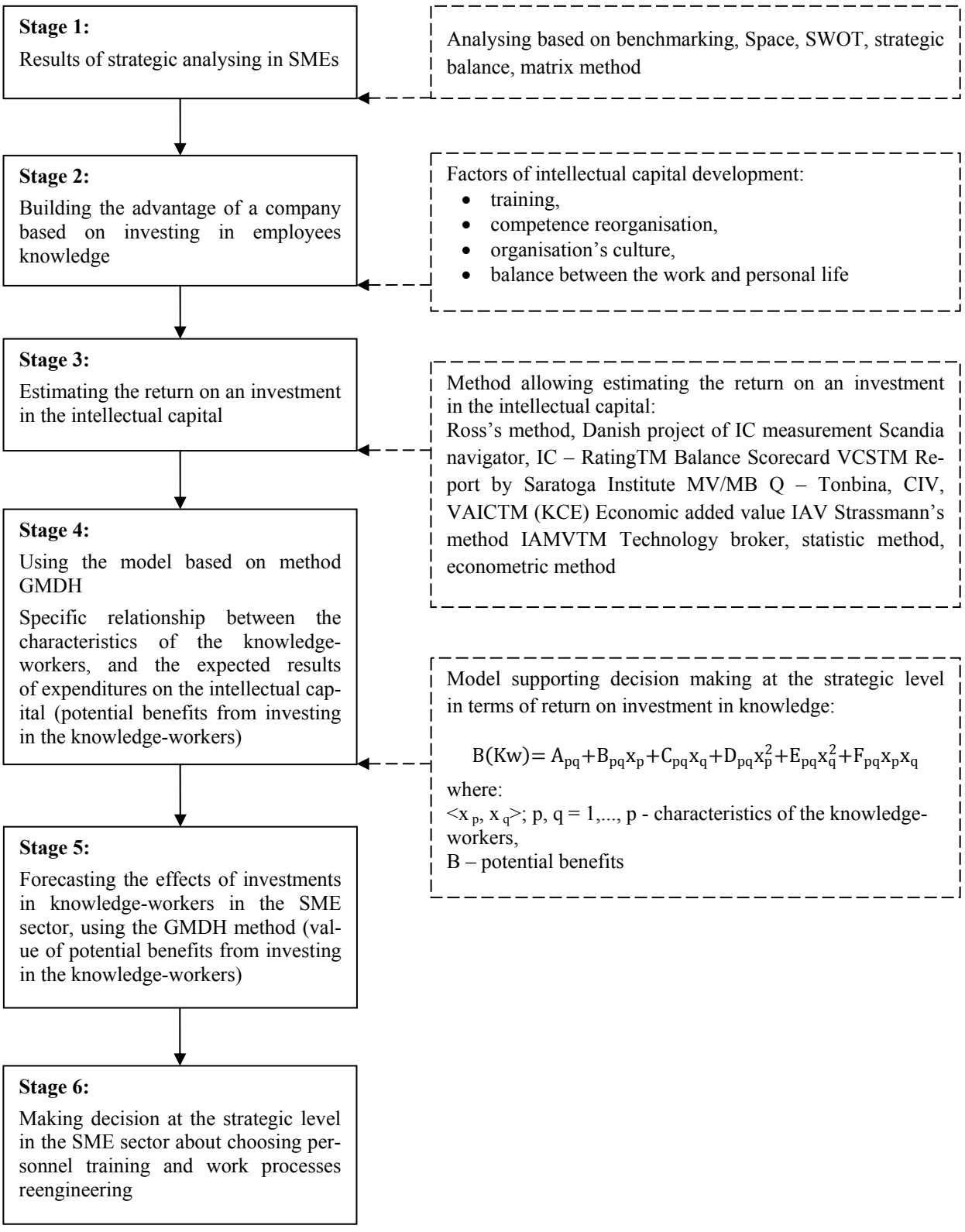

Figure 1. Conception of analysing the profitability of a strategic decision in terms of return on investment in knowledge *(source: self study)*

An attempt to define potential company benefits from investments in the human capital was made. The Group Method of Data Handling (GMDH) was adopted as a mean allowing for precise description of relationships between the input and output data in the given time horizon, guaranteeing independence from the subjective theoretical knowledge, and minimization of modeling errors. The set of knowledge-workers' traits' values and benefits in the SME sector company are considered the input data. It is suggested to use the GMDH algorithm as a genetic algorithm, with the following interpretation:

- the chromosome is a single multinomial as follows $A+Bx+Cy+Dx^2+Ey^2+Fxy$,
- the population is a set of multinomial examined in the current iteration,
- the evaluation (adjustment) function is the regularity criterion.

Setting up the structure for the model supporting decision making at the strategic level in terms of return on investment in knowledge with the parameter identification model of developed structure involves a great deal of calculation, especially in the case of the object high initial input number. The complication that the calculation of the algorithm involves was greatly reduced by implementing GMDH method. This method came into existence as a result of combination of LS Gauss optimization theory and Gödel logical openness theory, which makes a completion of the Iwachnienko hierarchical synthesis procedure.

Chapter three presents examples of applying the GMDH algorithm.

3. Practical examples of applying the GDMH algorithm

The basic assumption of the algorithm GMDH was to eliminate a deductive approach based on engineers and experts' knowledge. Another important element was the idea of polynomial evolution from its elementary structure to optimised one through selecting various combinations of simple partial models. In the majority of cased these are polynomials second degree with two variables. According to the concept, considering that at each iteration arguments supporting the elementary model are polynomial functions consisting of previous iteration, the degree of the resulting polynomial doubles at each stage of the algorithm. Optimised values of fixed parameters are calculated using the least square method. Many applications, developed after publishing GMDH, confirmed it efficiency and broad application [6].

There is a number of examples of practical application of GMDH based on retrospective data groups:

- in Great Britain, in 1980-1990, with the use of GMDH, a 10 year forecast of inflationary changes was developed for the country (GMDH model for inflation changes was identical with actual inflation in Great Britain in 1990-2000),
- in 1990-2000, in the United States, the GMDH method was used to develop a forecast for the development of main economic growth factors,
- in 1990-2000, in Ukraine, the GMDH method was used to develop a 10 year normative forecast for macro-economic processes,
- GMDH was used to develop a forecast for changes in lake Baikal,
- in 1990-2000, in the United States, the GMDH method was used in diagnosing cancer,
- in the early 70s, Adptronics Inc., US, used GMDH in a device for controlling quality of materials used in aviation,
- ComputerLand, Wrocław, Poland, uses GMDH for detecting failure of digital and analogue electronic system power supply,
- boiler house and steam station in the sugar plant in Lublin, Poland, use GMDH to control precision of technological track elements. Research concerning method development and integration (including GMDH) and process diagnosing techniques (in particular regulation valves) in the sugar plant in Lublin was provided under the project of DAMADICS (DAMADICS (Development and Application of Methods for ActuatorDiagnosis in Industrial Control Systems) – funded from the 5th Framework Programme in 2000-2003, project coordinator: Prof. Ronald J. Patton, University of Hull, Great Britain).

Multilevel algorithm GMDH enables us to perform optimisation synthesis of the mathematical model for a given class of the regression function and it can be used in evaluation criteria choice as well as the estimation quality assessment. Both elements of the algorithm are defined arbitrarily by the developer that is why modeling must be proceeded by an initial identification phase which allows for both defining the choice and the class of the solutions in progress.

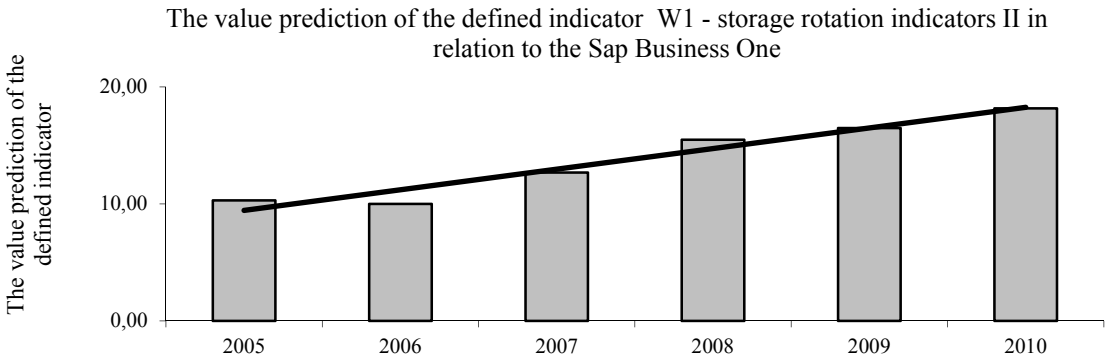

Figure 2. The value prediction of the defined indicator W1 – storage rotation indicators II in relation to the Sap Business One *(source: [13])*

Taking into account a specific kind of the objects in question, along with specific solution tasks supporting decision making at the strategic level in terms of return on investment in knowledge, it can be assumed that the regression function takes a form of two variables. A particle selection of integers is carried out with the regularity criteria.

Developing an object model with GMDH algorithm is carried out in steps. At every step the population regression integer is being generated. Because it was established that each of them is a function of two variables, the polynomials are assigned to every possible pairs of arguments. Their parameters are calculated using the method of the *least squares*, that is, using the sets of equation formulas. It can be concluded that GMDH procedure is conditioned by linear unit independence, which is a guarantee for the solution to be found [6].

Having generated the families of regressive polynomial, a selection takes place of those which approximately fit in interdependence under examination. Due to calculation assumptions, the restriction is assumed that the number of data (models) in a new population can not be higher than in the previous one.

For each population of particle solutions the lowest regularity criteria value is assigned (3). The steps 2 and 3 go through a loop until the value stops decreasing. It means that the optimal model was found which is a polynomial of regression for which the criteria has reached the lowest value.

There is an example of practical application of GMDH based on retrospective data groups [13, 14].

Let us consider the situation: the problem considered regards of chosen the ERP system objective and of assessment of effects of the system implementation. Enterprise resource planning (ERP) systems is an integrated software application used to support management and activities of organizations. Last years the strong competitions on the ERP market results with rapid development of the systems that today not only support resource planning needs but also integrate all departments and functions of a company [1, 3].

The best possible polynomial (decision model) in relation to the ERP: "Sap Business One" binding the selected indicators like W1 = labor efficiency indicator, W2 = storage rotation indicator II:

$$W(W_1, W_2) = 0{,}008\ W1 - 0{,}0002W2 + 0{,}00868W2^2$$

where:

W1 – storage rotation indicator II,

W2 – labor efficiency indicator.

The best possible polynomial (decision model) in relation to ERP: "the Comarch XL" binding the selected indicators like W1 = labor efficiency indicator, W2 = storage rotation indicator II:

$$W(W1,W2) = -46{,}58139 + 0{,}08647W1 + 1{,}07228W2 - 0{,}00007\ W1^2 - 0{,}03300\ W2^2 + 0{,}00099\ W1W2$$

where:

W1 – labor efficiency indicator,

W2 – storage rotation indicator II.

Decision model is contracted on the basis of the knowledge data base. It includes complex information about

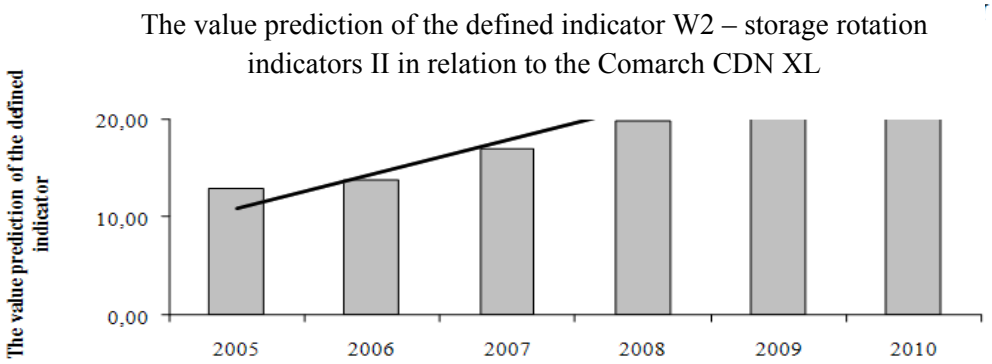

Figure 3. The value prediction of the defined indicator W2 - storage rotation indicators II, for Comarch CDN XL, (*source [13])*

all the processes, which could be observed while the date base was created, so both examples of successful and unsuccessful ERP system implementation are included. So, on the basis of the decision making model a forecast of a defined indicators value is introduced to the company A. As a result, the company A must make a decision as far as the purchase of the ERP system is concerned. This system is defined as Sap Business One, Comarch CDN XL, based on value forecasting.

So, on the basis of the data the function, which normalize the indicators W1, W2-assigned to the decision making model, is introduced. Consequently the normalize function for indicators W1, W2 (for ERP: "SAP Business One" and "Comarch XL") in decision models is shown in the Fig. 2. and in Fig. 3.

Sustainable increase can be observed in relation to the value of storage rotation indicator II. According to the definition the value storage rotation indicator II should increase with the development process of the company. Storage rotation indicator II refers to the interdependence where the increase in sale and the decrease in the storage volume (the direction of the value change of the parameters are among the others the indicators of the company development, thus the value of this indicator should also increase.

Based on the practical examples of applying the GDMH algorithm an attempt to define potential company benefits from investments in the human capital was made. The Group Method of Data Handling (GMDH) was adopted as a mean allowing for precise description of relationship between the characteristics of the knowledge-workers, and the expected results of expenditures on the intellectual capital (potential benefits from investing in the knowledge-workers).

4. Model supporting decision making at the strategic level in terms of return on investment in knowledge – case study

In accordance with the values of the characteristics of the knowledge-workers indicators and potential benefits from investing in the knowledge-workers here was constructed a decision model which contains the Group Method of Data Handling, which bounds this selected indicators. The data were collected in companies operating within the SME sector where an ERP system was applied.

In order to show the possibility of defining such a model let us consider the SME that deals with providing services for both organizations and individual customers (projects) and that has implemented ERP system (SME 1). The main areas of the SME 1 correspond to the following functions supporting: the sale, the supply, the orders scheduling, and the service. Company consists of 3 sell-departments.

The data (value of the characteristics of the knowledge-workers indicators and potential benefits from investing in the knowledge-workers) were collected from ERP system and from interview with management in enterprises.

Firstly, based on conception of supporting decision making at the strategic level in terms of return on investment in knowledge in the SME (Fig. 1) the stra-

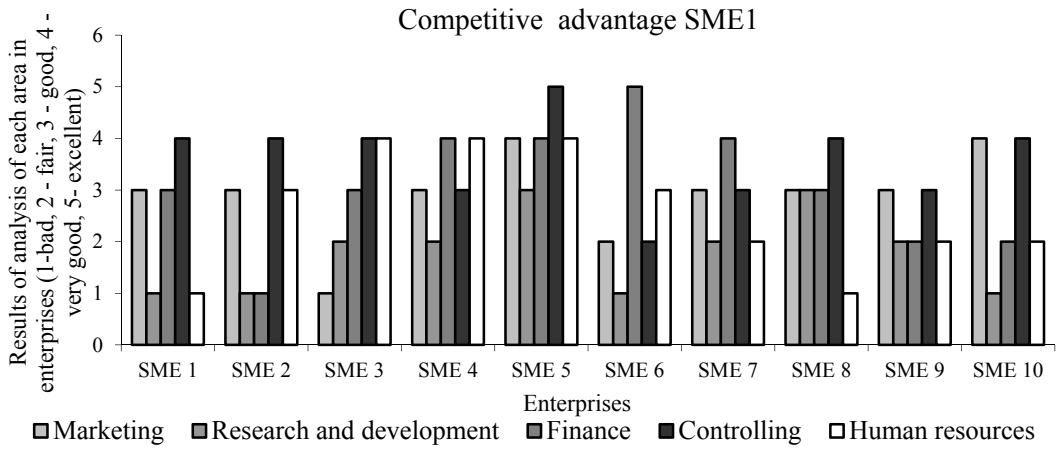

Figure 4. Results of strategic analysis of each area in enterprises – the strengths (*source: self study)*

tegic analisys was realized. Using of the strategic balance method, recommended directions for organization structure reform, were proposed for the company. The picture below (Fig. 4) shows results of analysis of the 10 enterprises SME sector in one region in Poland, which deals with providing services for both organizations and individual customers (projects).

The company (SME 1) is quite good in the area of marketing and controlling. As shown in the chart, there is a significant difference between answers about marketing and research and development. We can say that, in the field of human resource the company lacks competitive advantage. A decision for the investment in knowledge has to be made during the first step of building its competitive advantage in the areas of human resource. Staff is also a decisive factor for enhancing competitiveness. In the knowledge based economy, while trying to maintain their position in the market or access new markets, managers and employees need to improve their skills. This will help in being able to use innovative technologies that exist all over the world. Rapid changes force employees to put into practice the idea of life-long learning. Updating knowledge has become one of the most important civilization challenges of the information society [11].

The strategic analysis presented shows that there is negative result in the area of human resource. Also SMEs that are about to make decision concerning the investment in knowledge based on assessing the efficiency of human resource, tend to estimate the return on an investment in the intellectual capital, in the category of gaining the expected benefits.

The specific relationship between the characteristics of the knowledge-workers, and the expected results of expenditures on the intellectual capital (potential benefits from investing in the knowledge-workers) will be made on the results using GMDH method.

Secondly, a description will be provided on the findings of studies on the characteristics of the knowledge-workers (managers of 3 departments in SME 1) based on result of interview.

Characteristics of the knowledge-workers:

sell-manager 1

- C – creativity – ability to generate new, innovative ideas (index: number of ideas new solutions, created by the employee during a year): 3
- K – knowledge – proper processing and usage of information (index: results of a specialist test of the given employee, the test is constructed depending on the employee's profile, graded 1 to 5: 1-poor result, 5-the best result): 3
- Q – qualifications - education and professional experience (index: graduating from studies, postgraduate education, courses, trainings – secondary education: 1, higher education: 2, additional specialist courses: 3, post-graduate studies: 4, MBA studies: 5): 3

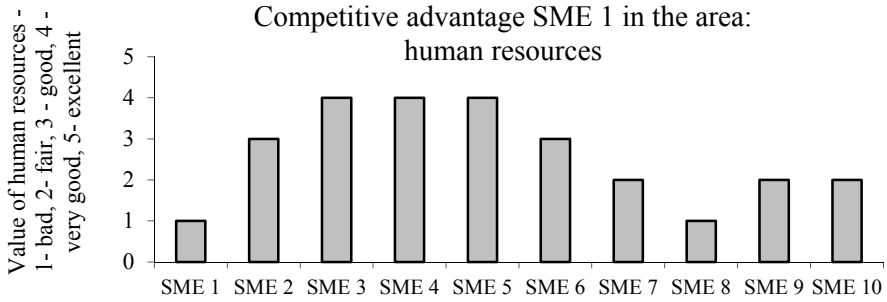

Figure 5. Results of strategic analysis of human resource area in enterprise – the strengths *(source: self study)*

- R – reliability – preciseness of the completed tasks (index: number of complaints from the customers during a year): 25
- S – skills – quality the completed tasks (index: work productivity): 11 391 536/ 2 411 294 = 4,72
- I – involvement – creating productive relations in a company (index: number of new customers gained during a year): 1 541
- H – honesty – completing tasks based on trust (index: number of employees' meetings in which the employee participated and given a new ideas to the number of all the meetings during a year): 8/13 = 0,61.

Characteristics of the knowledge-workers:

sell-manager 2

- C – creativity – ability to generate new, innovative ideas (index: number of ideas (new solutions, created by the employee during a year): 10
- K – knowledge – proper processing and usage of information (index: results of a specialist test of the given employee, the test is constructed depending on the employee's profile, graded 1 to 5: 1-poor result, 5-the best result): 3
- Q – qualifications - education and professional experience (index: graduating from studies, postgraduate education, courses, trainings – secondary education: 1, higher education: 2, additional specialist courses: 3, post-graduate studies: 4, MBA studies: 5): 2
- R – reliability – preciseness of the completed tasks (index: number of complaints from the customers during a year): 40
- S – skills – quality the completed tasks (index: work productivity): 16 323 553/ 1 444 700 = 11,29
- I – involvement – creating productive relations in a company (index: number of new customers gained during a year): 1 920
- H – honesty – completing tasks based on trust (index: number of employees' meetings in which the employee participated and given a new ideas to the number of all the meetings during a year): 7/13 = 0,53.

Characteristics of the knowledge-workers:

sell-manager 3

- C – creativity – ability to generate new, innovative ideas (index: number of ideas, new solutions, created by the employee during a year): 1
- K – knowledge – proper processing and usage of information (index: results of a specialist test of the given employee, the test is constructed depending on the employee's profile, graded 1 to 5: 1-poor result, 5-the best result): 2
- Q – qualifications - education and professional experience (index: graduating from studies, postgraduate education, courses, trainings – secondary education: 1, higher education: 2, additional specialist courses: 3, post-graduate studies: 4, MBA studies: 5): 2
- R – reliability – preciseness of the completed tasks (index: number of complaints from the customers during a year): 10
- S – skills – quality the completed tasks (index: work productivity): 18889867/ 1606154 = 11,7
- I – involvement – creating productive relations in a company (index: number of new customers gained during a year): 2 137
- H – honesty – completing tasks based on trust (index: number of employees' meetings in which the employee participated and given a new ideas to the number of all the meetings during a year): 13/13 = 1.

Using of the data from ERP systems the indicators value of the potential benefits for each department are defined (Table 4).

SMEs that are about to make strategic decision concerning the organization of training for sell-managers tend to make a preevaluation of the efficiency of their very implementation (for example taking into consideration the level of the user's objectives realization). It was concluded that on the basis of the author's model supporting decision making at the strategic level in terms of return on investment in knowledge, the company will obtain the prediction of the defined indicators value the potential benefits before investment in training for sell-manager.

The method GMDH and the data base form company enable us to carry out an assessment of investment in knowledge. The precisely defined criteria of the potential benefits are ascribed form ERP system (Table 4), which allows us to define the potential values of these parameters before the investing in knowledge.

So, for the object from Table 3 of the output C,…, H and of one output y the matrix X is made:

$$X = \begin{bmatrix} C & K & Q & R & S & I & H \\ 2 & 3 & 3 & 25 & 4,72 & 1541 & 0,61 \\ 10 & 3 & 2 & 40 & 11,29 & 1920 & 0,53 \\ 1 & 2 & 2 & 10 & 11,7 & 2137 & 1 \end{bmatrix}$$

Columns 1,..., 7 represent independent variables C,…, H and vector y of the output value SWC = [0,56; 0,57; 0,64]^t. It is assumed that the columns of the matrix X are line independent.

In the first step, for each pair of independent variables the polynomials is created approximating the overall form:

$$y^* = A_{pq} + B_{pq}x_p + C_{pq}x_q + D_{pq}x_p^2 + E_{pq}x_q^2 + F_{pq}x_px_q$$

which is called Iwachienko polynomial (Table 5).

Altogether there are 42 polynomials. Each polynomial is being evaluated for all the observation from the X matrix. The values that are calculated are placed in separate supporting columns of Z matrix:

$$Z = \begin{bmatrix} Y^*_1 & Y^*_2 \ldots & Y^*_{42} \\ -1,6352 & 0,5193 \ldots & 0,6329 \\ -1,6248 & 0,5193 \ldots & 0,6608 \\ -0,8235 & 0,5893 \ldots & 0,7411 \end{bmatrix}$$

In the second step, for each column j = 1, 2,..., 42 of
Z matrix an equality criterion is assigned from the formula:

$$r_j^2 = \frac{\sum_{i=t+1}^{n}(y_i - z_{ij})^2}{\sum_{i=t+1}^{n} y_i^2}$$

where:
i – following observation of matrix X,
j = 1, 2, .., 42 matrix Z.

In the third step, the selection of the best polynomials takes place – of the least r factor value. If it is assumed that there is some stability in polynomial from Z matrix a selection of m column can be made, which are assigned to X matrix. In this way the output data become the input data for the next generation process.

So, in the following steps of the process we can come up with two polynomials with the least value of r_j^2 factor:

$$Y^*_{31} = Y^*_{34} = 0,8000 - 0,0700\,K - 0,0100\,Q$$

$$Y^*_{41} = 0,4553 + 0,0033\,S + 0,1461H$$

$$Y^*_{18} = 0,4228 + 0,2138\,H + 0,0034\,C,$$

where:
K – knowledge,
Q – qualifications,
C – creativity,
S – skills,
H – honesty.

Table 3. Results of research of characteristics of the knowledge-workers: sell-manager (*source: self study)*

	C	**K**	**Q**	**R**	**S**	**I**	**H**
M1	2	3	3	25	4,72	1541	0,61
M2	10	3	2	40	11,29	1920	0,53
M3	1	2	2	10	11,7	2 137	1

Table 4. Results of research of the potential benefits *(source: self study)*

	ROE	**ROA**	**ROS**	Share working capital in assets - SWC	Number of paten (license)	Number of innovative project
D1	4,84	2,18	0,80	0,56	0	0
D2	4,64	1,79	0,67	0,57	0	0
D3	5,33	1,74	0,67	0,64	0	1

Table 5. The polynomials for each pair of independent variables, *(source: self study)*

Pair of independent variables	**Polynomial**	**Pair of independent variables**	**Polynomial**
(C, K)	$Y^*_1 = 0{,}8012 + 0{,}0013\,C - 0{,}813K$	(I, K)	$Y^*_{22} = 0{,}7122 - 0{,}0643K$
(K, I)	$Y^*_2 = 0{,}7293 - 0{,}07K$	(I, C)	$Y^*_{23} = 0{,}3749 + 0{,}0001\,I - 0{,}0047C$
(K, H)	$Y^*_3 = 1{,}0225 - 0{,}1287W - 0{,}1250\,Hc$	(S, R)	$Y^*_{24} = 0{,}5847 + 0{,}0066S - 0{,}0022R$
(Q, R)	$Y^*_4 = 0{,}7533 - 0{,}0450Q - 0{,}0023R$	(S, Q)	$Y^*_{25} = -3{,}5810 + 0{,}1707 - 1{,}1117Q$
(Q, S)	$Y^*_5 = -3{,}5810 + 1{,}1117Q + 0{,}1707S$	(S, W)	$Y^*_{26} = 0{,}7609 + 0{,}0015S - 0{,}0694W$
(Q, I)	$Y^*_6 = -0{,}2739 + 0{,}1123Q - 0{,}0003I$	(S, C)	$Y^*_{27} = 0{,}5254 + 0{,}0104S - 0{,}0073C$
(Q, S_c)	$Y^*_7 = 0{,}5349 - 0{,}0219Q - 0{,}1489Sc$	(R, Q)	$Y^*_{28} = 0{,}7533 - 0{,}0023R - 0{,}0450Q$
(C, Q)	$Y^*_8 = 0{,}8012 + 0{,}0013C - 0{,}0813Q$	(R, W)	$Y^*_{29} = 0{,}8133 + 0{,}0007R - 0{,}0900W$
(C,R)	$Y^*_9 = 0{,}6890 + 0{,}0129C - 0{,}0062R$	(R, C)	$Y^*_{30} = 0{,}6890 - 0{,}0062R + 0{,}0129C$
(C, S)	$Y^*_{10} = 0{,}5254 - 0{,}0073C + 0{,}0104S$	(Q, W)	$Y^*_{31} = 0{,}8000 - 0{,}0100Q - 0{,}0700W$
(C, I)	$Y^*_{11} = 0{,}3749 - 0{,}0047C - 0{,}0001I$	(Q, C)	$Y^*_{32} = 0{,}7922 - 0{,}0722Q - 0{,}0078C$
(C, H)	$Y^*_{12} = 0{,}4228 + 0{,}0034C - 0{,}2138H$	(W, C)	$Y^*_{33} = 0{,}8012 - 0{,}0812W - 0{,}0013C$
(H, I)	$Y^*_{13} = 0{,}4028 + 0{,}1246H - 0{,}0001I$	(W, Q)	$Y^*_{34} = 0{,}8000 - 0{,}0700W - 0{,}0100Q$
(H, S)	$Y^*_{14} = 0{,}4553 + 0{,}1461H - 0{,}0033S$	(W, R)	$Y^*_{35} = 0{,}8133 - 0{,}0900W - 0{,}0007R$
(H, R)	$Y^*_{15} = 0{,}3275 + 0{,}2903H - 0{,}0022R$	(W, S)	$Y^*_{36} = 0{,}7609 - 0{,}0694W - 0{,}0015S$
(H, Q)	$Y^*_{16} = 0{,}5349 + 0{,}1489H - 0{,}0219Q$	(R, S)	$Y^*_{37} = 0{,}5847 - 0{,}0022R + 0{,}0066S$
(H, W)	$Y^*_{17} = 1{,}0225 - 0{,}1250H - 0{,}1288W$	(R, I)	$Y^*_{38} = 0{,}4594 - 0{,}0017R + 0{,}0001I$
(H, C)	$Y^*_{18} = 0{,}4228 + 0{,}2138\,H - 0{,}0034C$	(R, H)	$Y^*39 = 0{,}3275 + 0{,}0022R + 0{,}2903H$
(I, S)	$Y^*_{19} = 0{,}0976 + 0{,}0004I - 0{,}0192S$	(S, I)	$Y^*_{40} = 0{,}0976 - 0{,}0192S + 0{,}0004I$
(I, R)	$Y^*_{20} = 0{,}4594 + 0{,}0001I - 0{,}0017R$	(S, H)	$Y^*_{41} = 0{,}4553 + 0{,}0033S + 0{,}1461H$
(I, Q)	$Y^*_{21} = -0{,}2739 + 0{,}0003I + 0{,}1123Q$	(I, H)	$Y^*_{42} = 0{,}4028 + 0{,}0001I + 0{,}1246H$

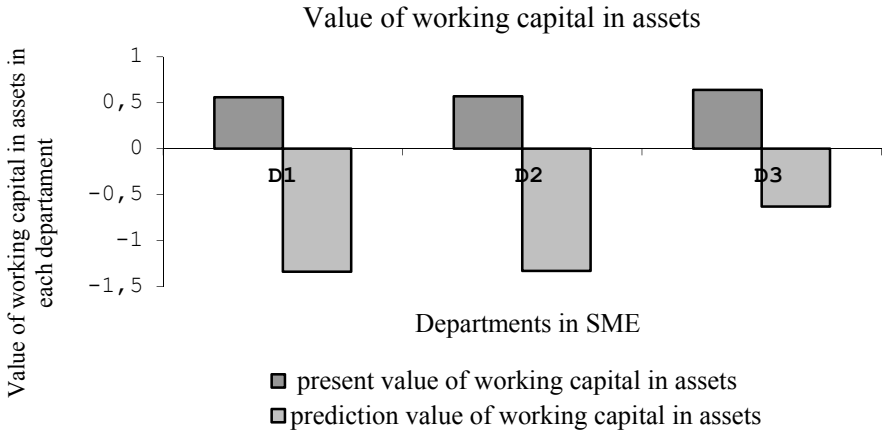

Figure 6. Prediction value of knowledge in the SME sector using the model 1
(source: self study)

So, the best possible polynomial (decision model) in relation to share working capital in assets indicators binding the selected criteria of the characteristics of the knowledge-workers is defined:

$$Y^*_{31} = Y^*_{34} = 0{,}8000 - 0{,}0700\ K - 0{,}0100\ Q \qquad (1)$$

or, as secondly

$$Y^*_{41} = 0{,}4553 + 0{,}0033\ S + 0{,}1461 H \qquad (2)$$

For a company, investing in the knowledge-workers comes down to organizing trainings for the sell-managers. Using the model (1) the effects f investments in knowledge-workers in the SME sector (prediction value of share working capital in assets) is forecasted (Fig. 6).

So, investing in the intellectual capital (training for sell-manager) is not profitable, because the value of the potential benefits (prediction value of share working capital in assets) is not acceptable for the management of the SME sector company.

But, when for a company investing in the knowledge-workers comes down to changing the organisation culture, the analysis results are acceptable for management in SME. Using the model (2) the effects of investments in knowledge-workers in the SME sector (prediction value of share working capital in assets) is forecasted (Fig. 7).

As a result, on the basis of the obtainable prediction values, it was recommended to the company to investment in building an organization's culture based on confidence. Trust and confidence are both the target the strategy and determinants of strategy preferences. Trust is voluntary and linked to shared values [Tonkiss and Passey, 1999]. Confidence in knowledge-workers management should be interest centre both employee and management.

The matrix of the characteristics of the knowledge-workers will help assessing rationality and effectivenes of investing in employee skills, namely training for employees. Future research include developing a system of indicators which, on the one hand, will reflect funding spent on training and, on the other, will include measures to show effects of such investment. Indicators, defined on the basis of experience among SMEs which invested in knowledge and operate ERP tools, will comprise a base of parameters and indicators necessary to build a system supporting decision making at a strategic level as regards profitability of investing in knowledge. It means that, for some companies, the assessment of the effects which investment in knowledge would bring can be done on the basis of previously defined indicators.

Developing a decision making model will start with collecting information on the more research subject. These are empirical data obtained through observation of SMEs operation. Model identification indicators enabling to asses rationality and effectiveness of knowledge based on measurement of input and output data from SMEs studies using GMDH algorhytm.

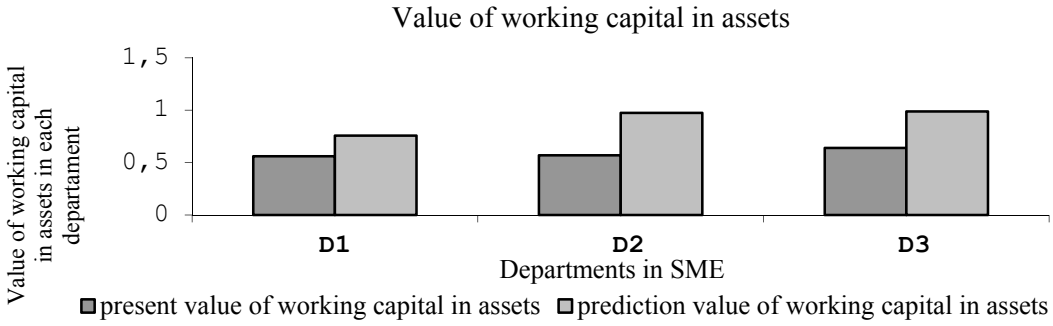

Figure 7. Prediction value of knowledge in the SME sector using the model 2
(source: self study)

5. Concluding remarks

Companies operating in a market economy need to introduce changes in systems of organisation and management. In business practice, decision making in a company depends on activity, competition, changing external factors, e.g. technical advancement, and results achieved by research and development departments. Knowledge, employees' skills, social relations, know-how, and in particular effective investment in intellectual are an added value for a company. Companies investing in human capital and work systems acquire competitive advantage thanks to their readiness to learn and adopting new qualifications as well as efficient communication and information channels.

The model which has been introduced in this paper gives more possibilities in the area of profitability of the investment in knowledge. The research which is in progress is focused on the development of the SME knowledge database of characteristics of the knowledge-workers. A decisive nature of an undertaken problem imposes the structural model of identification.

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