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Ladies and Gentlemen,

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

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

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

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

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

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

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

Tadeusz Krupa

CONTENTS

CLASSICAL AND QUANTUM PHYSICS IN SELECTED ECONOMIC MODELS

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Abstract: A growing number of economic phenomena are nowadays described with methods known in physics. The most frequently applied physical theories by economists are: (1) the universal gravitation law and (2) the first and second law of thermodynamics. Physical principles can also be applied to the theory of financial markets. Financial markets are composed of individual participants who may be seen to interact as particles in a physical system. This approach proposes a financial market model known as a minority game model in which securities and money are allocated on the basis of price fluctuations, and where selling is best option when the vast majority of investors tend to purchase goods or services, and vice versa. The players who end up being on the minority side win.

The above applications of physical methods in economics are deeply rooted in classical physics. However, this paper aims to introduce the basic concepts of quantum mechanics to the process of economic phenomena modelling. Quantum mechanics is a theory describing the behaviour of microscopic objects and is grounded on the principle of wave-particle duality. It is assumed that quantum-scale objects at the same time exhibit both wave-like and particle-like properties. The key role in quantum mechanics is played by: (1) the Schrödinger equation describing the probability amplitude for the particle to be found in a given position and at a given time, and as (2) the Heisenberg uncertainty principle stating that certain pairs of physical properties cannot be economic applications of the Schrödinger equation as well as the Heisenberg uncertainty principle. We also try to describe the English auction by means the quantum mechanics methods.

Key words: quantum mechanics, minority games, equilibrium, English auction.

1 Introduction

The application of the laws of physics in economic theory has become a prominent trend for several decades. Economists have most often referred to the law of gravitation, static physics and the first and second law of thermodynamics. Gravitation models were pioneered in the early 1900s by J. Q. Stewart who defined the concept of demographic force (as an equivalent of potential energy) and demographic potential based on the theory of the field of gravity. Gravitation models became popular in many areas of economic study in the early 1960s, e.g. the description of interaction between economic centres or international trade exchange.

The rules of thermodynamics, which generally state that the increase of internal energy of a system is equal to the difference between the amount of energy delivered to the system and the amount of energy released by the system into the environment, have been applied in the theory of economic equilibrium which can be expressed in a number of ways. Equilibrium has been studied by classical economists such as A. Smith, A. Cournot, W. Pareto, and recently by J. Tinbergen, P.A. Samuelson, J.R. Hicks, R. Selten, J.F. Nash, R. Lucas and others.

Static physics, which focuses on electromagnetic interactions, has been applied in the financial markets theory. A financial market is defined here as a system made up of a number of individual participants who interact with one another in an electromagnetic-like manner. This approach to financial markets developed a minority game market model, where assets (stocks and money) are allocated solely based on price fluctuations: if the majority of investors are willing to buy it is more profitable to sell and vice versa. Minority players are winners.

So far, we have looked at classical physical concepts applied in economic theory. This paper also attempts to demonstrate the benefits of applying quantum mechanics in economic modelling. Developed around 1926, quantum mechanics is a theory describing behaviours of micro-objects in the framework of its principal concept of wave-particle duality. Micro-objects are believed to be simultaneously characterised by a wave function and properties of elementary particles.

The key formula of quantum mechanics is one developed by E. Schrödinger, which determines the probability of a micro-object's being in a specific state. The other cornerstone of the theory is the Heisenberg uncertainty principle which states that no two different physical quantities of a studied object can be determined with any accuracy at the same time. This paper attempts to identify possible economic applications of both the Schrödinger equation and the Heisenberg principle. Special attention is given to a quantum model of English auction.

The structure of this paper is as follows: Part Two reviews selected economic concepts where modelling is based on laws of classical physics such as gravity, the first and second law of thermodynamics and static physics; Part Three provides a brief description of quantum mechanics, including the presentation of the Schrödinger equation and the Heisenberg principle, and suggests possible applications in economics; Part Four presents an attempted description of the English auction using the laws of quantum mechanics.

2 Review of economic applications of the laws of physics

2.1 Gravitation models

Economic models that use the basic laws of physics have been known since the 1960s. The most frequently applied are the law of gravity and the first and second law of thermodynamics.

In physics, gravity is the property of matter which consists in a mutual attraction between material bodies. The theory of gravity, also known as the Newtonian mechanics, is believed to have been first proposed by I. Newton (1687). In the Newtonian (classical) mechanics, the mass of a material point is defined as a positive scalar value which is the measure of the point's inertia. It is agreed that the mass of an object is independent of its movement status (it is constant) and is not affected by any processes within it.

This is known as the law of conservation of mass. Force is defined as vector value that illustrates the measure of mechanical impact of other objects on the body at hand. This is the way object may but do not have mutually exchange energy. Energy is a physical scalar value which is the general measure of the various forms of movements of matter that are contemplated by physics. Classical mechanics observes the principle of relativity, which says that the principles of mechanics shall be identical for all inertia reference systems, i.e. all mechanical processes that occur in the same conditions shall progress identically.

The law of universal gravity is one of the most widely known laws of classical physics. It states that every two material points shall mutually attract with force which is directly proportional to the product of the masses of both points and reversely proportional to the square of the distance between them, i.e.:

$$F = G\frac{m_1 m_2}{r^2} \tag{1}$$

where:

m_1, m_2 - are the masses of material points,

r - is the distance between such points,

G - is the proportionality constant,

F - is the force of gravity.

The gravitational force is not a quantity that characterises the gravitational field. The gravitational field is quantified by the gravitational field strength expressed as follows:

$$\gamma = \frac{M}{r^2} \tag{2}$$

where *M* is the mass of the source.

Economic theory also applies the concept of potential energy, as described by the following formula:

$$E_p = -G\frac{Mm}{r} \tag{3}$$

Potential energy reflects the work done when a body is moved from one level to another. The gravitational field is characterised by a potential expressed as follows:

$$V = -G\frac{M}{r} = \frac{E_p}{m} \tag{4}$$

Potential is a physical quantity that specifies energy properties of the gravitational field at one point.

The first attempts at applying gravitational models in spatial economic research were made in early 20th century. However, the pioneering work in this field came from demographer J.Q. Stewart, who defined the demographic force concept as a counterpart to potential energy or gravitational field potential (1947). Proper gravitational models used in economic theory date back to the 1960s.

Material points were replaced by 'centres' such as cities, shopping centres and the term 'gravitation' was replaced by its economic equivalent: interaction. One of the initial models was expressed as:

$$I_{ij} = G\frac{P_i P_j}{d_{ij}^{\ c}} \tag{5}$$

where:

I_{ij} - means interaction (impact) between area i and j,

P_i, P_j - are masses of two areas which can be measured by the size of their populations,

d_{ij} - is the distance between area i and j,

G - is the equivalent of gravitation force which is referred to as calibration constant in economics,

c - is the exponent of the power of the distance.

Units (masses) can be countries, economic regions, administrative provinces, cities or towns. Depending on the problem at hand, mass is measured in the number of households, number of consumption sites, number of warehouses and outlets, surface of retail or storage space, number of hospital beds, newspaper and magazine circulation, population etc. Distance is measured in kilometres, time of travel or the quotient of the product of price and time of travel. The calibration constant is model-specific and it is assessed so as to fit the model to the data.

There are a number of areas where gravitation models can be applied. For example, market researcher W. Reilly examined ways of assessing the sales proportion s_i of the same goods offered by two mutually competing cities M_1 and M_2 to and smaller town m_0 located between them. He quantified the impact of city M_i (i = 1,2) with mass P_i (mass measured in population size) with distant by d_i on goods available to town m_0. The relationship w_i is illustrated by the formula:

$$w_i = \frac{P_i}{d_i^{\ 2}} \tag{6}$$

Impact w_i refers to the concept of gravitational field. The sales ratio for two comparable cities is expressed as follows:

$$\frac{s_1}{s_2} = \frac{w_1}{w_2} \tag{7}$$

which means that the value of sales in town m_0 realised by the competing cities is proportional to their impacts.

By substituting values w1 and w2 (formula (6)) you get the following expression:

$$\frac{s_1}{s_2} = \frac{P_1}{d_1^2} : \frac{P_2}{d_2^2} = \frac{P_1}{P_2}\left(\frac{d_2}{d_1}\right)^2 \tag{8}$$

Subsequently, the right-hand side of formula (8) is compared to 1 and then you quantify the reach of the competing market in the following way:

$$\frac{s_1}{s_2} = \frac{P_1}{P_2}\left(\frac{d_2}{d_1}\right)^2 = 1, \ \frac{d_2}{d_1} = \sqrt{\frac{P_2}{P_1}} \tag{9}$$

If you accept that $d_{12} = d_1 + d_2$ and you substitute the relevant values into formula (9) you get the 'optimum' distances of both cities from town m_0:

$$d_1 = \frac{d_{12}}{1+\sqrt{\frac{P_2}{P_1}}}, \ d_2 = \frac{d_{12}}{1+\sqrt{\frac{P_1}{P_2}}} \tag{10}$$

'Point' d_{12} is the point of separation between the two trading centres.

Here is another interesting model that determines trade exchange mechanisms between two countries. P. Krugman [5] uses the following equation to quantify trade between two countries:

$$T_{ij} = \frac{AY_i Y_j}{D_{ij}^{\ c}} \tag{11}$$

where:

A - is a constant,

T_{ij} - means the value of trade between country i and country j,

D_{ij} - is the distance between country i and j,

Y_j - is the GDP of country j,

c - is exponent of the power of distance.

Formula (11) entails that the value of trade is directly proportional to the product of GDP of the countries at hand and it decreases as the distance increases. The gravitational model demonstrates that trade between two countries is dependent on the size of their economies and is negatively affected by the distance between them. Other gravitational models describing spatial economic interactions were proposed by W. Reilly, M. Cadwallader, R. Bachi, T. Stanley, M. Sewall, P.D. Convers, D.L. Huff (Balicki [1]).

2. 2 The law of conservation of energy and the theory of economic equilibrium

Another example of fundamental laws of classical physics that have found applications in economic theory and social science is that of the general law of coservation of energy and the first law of thermodynamics. The law of conservation of energy says that the energy of a body or a system of bodies cannot come from nothing or disappear without a trace. One type of energy may merely convert into another and the total energy in an isolated system remains constant: $E_c = \text{const.}$

The first law of thermodynamics, independently formulated by J.R. Mayer in 1842 and H.L.F. Helmotz in 1847, is the law of conservation of energy proper in thermodynamics and it says that the internal energy of a system is solely the function of its state, i.e. is solely dependent on parameters that characterise the state of the system's equilibrium. It does not depend on the processes that have caused the system to be in that state. The increase of the system's internal energy is equal to the difference between the energy supplied to the system and the energy released by the system into the environment.

These laws have for many years been nearly intuitively applied in economics, mainly for describing economic equilibrium. The concept of economic equilibrium is ambiguous. Most commonly it is used to describe the balance between supply and demand for all goods (general equilibrium) or specific goods (partial equilibrium). It is widely accepted that economic systems are subject to numerous forces (often disturbing) but their overarching property is that they always tend toward equilibrium which is not necessarily the same as in the past.

The history of the concept of economic equilibrium goes back to the 17th century. Adam Smith (1723 - 1790) in his groundbreaking work entitled "An Inquiry into the Nature and Causes of the Wealth of Nations" stated that an 'invisible hand of the market' (force) causes interactions between participants of an unbridled economy, or free market, to be harmonised, which then leads toward a market equilibrium. Thus, he introduced the concept of natural equilibrium. Around the same time, F. Qusnay (1694 - 1774) presented the Economic Table outlining the flows of value between the branches of economy, or an economic system which is subjected to certain economic factor but is in equilibrium. A. Cournot (1801 - 1877) pioneered the use of functional relationships in research of economic developments, which helped identify the differences between partial and general equilibrium. L. Walras (1834 - 1910), the creator of the price theory, applied the general equilibrium system to state that there is a close interdependency between the capital market, prices and the markets for products and services and all of the above affect each other. Any growth noted on any of the markets is reflected in the decreased potential of another, just like in a thermodynamic system. W. Pareto (1848 - 1923) claimed the existence of a lasting equilibrium to which economic systems return, favourable circumstances permitting, which offers a clear analogy to the law of conservation of energy.

Equilibrium and the 'forces' affecting economic systems can be expressed in a number of ways in economic theory. Originally, it was believed that an economy in equilibrium could be described with linear equations and inequalities. Underlying to this view was an assumption that equilibrium is preconditioned by a steadily growing economy. In such case, finding point (vector) of equilibrium X_0 would require solving system of equations $AX = B$ and inequalities $X \geq 0$ with a specified function of objective f (criterion). The value of X_0 is selected so that the objective function reaches the least value of all the solutions representing acceptable decisions. Such a minimum is naturally associated with equilibrium as does the minimum position of the pendulum in physics.

Over time, it was observed that the economic reality, as indeed physical reality, is fairly 'non-linear'. Nonlinear systems are more difficult to analyse than linear ones. The economic reality can be described using a system of non-linear differential equations and each object can have several positions (points) of equilibrium. Some of such points will be points of stable equilibrium and some will be short run, which means that there may be a position of equilibrium both with a minimum potential and kinetic energy.

The stability of the point of equilibrium further depends on the forces (distortions) operating against a specific economic object trying to throw it out of equilibrium. They may also change the position of the equilibrium point. Generally, the search for equilibrium in nonlinear dynamic systems requires that the evolving trajectory is defined. In specific cases, it may act chaotically. If this happens equilibrium can only be found by identifying the attractor and the attractor may turn out to be strange (Schuster [8]).

2. 3 Financial market modelling using minority games

The last decade saw the rise in popularity of a financial market model called the minority game, which operates in a similar fashion to a macroscopic system in static physics. Market participants whose numbers are high (they are often referred to as a 'continuum') buy and sell securities. They rely on the analysis of the stock price fluctuation and other information they receive. If the majority of market participants intend to buy a stock it makes sense to sell, and vice versa. Minority group participants usually win. All market participants make decisions based on their experience and certain information patterns. There are three types of participants in a minority game depending on their response to available information: players who create information noise and make random decisions, producers who behave in a deterministic way and speculators who seek profit using all methods available. The activities of all three groups cumulate and cause qualitative change
of the entire system, as is the case in typical macroscopic physical systems where electromagnetic impacts are observed in the macro scale. Here, it is unnecessary to understand the impacts between elementary particles that make up the system because they are too small. From the point of view of a market participant it is essential to identify such parameters of the system which characterise the system's status in a macro scale. Because there are large numbers of participants, the laws of large numbers are often used (Challet et al. [2], Mosetti et al. [7]).

Minority games may be described as follows:

1) The financial market is assumed to be a non-zero sum game with N players ($N \to \infty$).
2) At any stage of the game (t = 1, 2, ...), each player may but does not have to make one of two decisions: 'buy' or 'sell', which can be expressed as $a_i(t) = +1$ or $a_i(t) = -1$.
3) The payout (profit) of the i-th player is described by the following formula:

$$g_i(t) = -a_i(t)A(t), \text{ where } A(t) = \sum_{j=1}^{N} a_j(t) \qquad (12)$$

A(t) denotes the difference between the number of players who decided to sell and the number of players who buy a stock at time t. If $A(t) > 0$ the players who play $a_i(t) = -1$ will win and those who chose $a_i(t) = +1$ will lose.

4) Strategy $s_i(t)$ of player i at time t (i = 1, ... N; t = 1, 2, ...) is assessed based on information {1, ... μ, ... P} obtained by players as the game proceeds. It is defined as follows: $s_i(t)$: $\{1, \dots \mu, \dots P\} \to \{-1; +1\}$. In this case, information includes both the game history, or a string of minority and majority players' decisions in the past and certain information received from outside.
5) While considering both the received information and the 'adaptability' of individual players the profit of the i^{th} player can be expressed as follows:

$$g_i(t) = -a_i(t)^{\mu(t)}_{s_i(t),i} A^{\mu(t)}(t)$$

where

$$A^{\mu(t)}(t) = \sum_{j=1}^{N} a^{\mu(t)}_{s_j(t),j}(t) \qquad (13)$$

where

$$a_i(t) \to a_i(t)^{\mu(t)}_{s_i(t),i} \quad \text{and} \quad A(t) \to A^{\mu(t)}(t)$$

6) The goal of each market participant is profit maximisation $g_i(t)$ (i = 1, ... N) at any stage of game t.

The problem can solved in a number of ways (Challet et al. [2], Mosetti et al. [7]). Financial market researchers who concentrated on minority game modelling have also focused on examining function A(t). Variance $\sigma^2(t) = \langle A(t) \rangle$ of quantity A(t) measures the distribution of financial resources in the market. In addition, researchers study:

$$\alpha = \frac{P}{N}$$

When $\alpha >> 1$ there is too much information circulating in the market and players act randomly. When $\alpha \to 1$ more players join the game and the information received is used more efficiently. When α reaches its minimum

$$\left(\alpha = \frac{7}{20}\right)$$

the behaviour of market participants can be compared to the description of critical phenomena in static physics.

The probability of each player making a specific decision is determined as follows:

$$\text{Prob}\left\{a_i(t) = \pm 1\right\} = \frac{e^{\pm g_i(t)}}{e^{g_i(t)} + e^{-g_i(t)}} \tag{14}$$

Notably, minority games are based on a classic binary game called ‘bar’ (El’Farol bar problem) invented by W.B. Arthur where participants are obliged to make a decision each night whether or not to go to a bar.

The economic models presented thus far ‘apply’ the laws of classical physics. The following chapter presents the use of quantum mechanics in modelling economic phenomena.

3 The application of quantum mechanics in economics

3.1 Basics of quantum mechanics

Quantum mechanics is a theory describing the behaviour of elementary particles in atomic scale. The biggest accomplishment of quantum physics is the wave-particle duality. According to this theory, photons and electrons, light and matter are both waves and particles. An object such as an electron is a particle because of its spatial delineation and a wave because the way it moves in space. The following discussion will use the term micro-objects instead of particles.

Quantum mechanics says that nature can be described in approximated terms and each measurement is biased with a probability and accuracy. Uncertainty and inaccuracy are not caused by the inaccuracy of measuring equipment but are inherent to the phenomena themselves. It should be underlined, however, that quantum physics is characterised by an absolute determinism but exclusively in the space of states. Indeterminism starts when you move to the physical space and ask about the coordinates of a micro-object.

The major accomplishment of quantum mechanics is that it has rejected the classical division into the observed and the observer. In classical physics, the observer cannot influence the state of an object under observation or measurement. In quantum mechanics it is acceptable to assume that micro-objects may be located in several places at the same time by the time of observation. Also, they may be so strongly linked (quantum entanglement) that they may act as unity regardless of the distance between them. This property has its economic analogy. For example, strongly linked subsidiaries of a major corporation may be located in different parts of the world. Despite the distance between them they form one big ‘organism’.

The fundamental concept of quantum physics is a space of states of physical systems that forms a vector Hilbert space[1]. The state of a system is represented in quantum mechanics by unit vectors. That is known as the pure state. The scalar product is used for assessing the probability of measurement of any physical quantity.

Each physical quantity is additionally represented using a Hermitian operator[2]. The values of the operator are real numbers and this is why they are not interpreted as quantities to be obtained through measurement. After the measurement is taken, the system is in one of the Hermitian operator’s own states which represents a given observable, as outlined by J. von Neuman. The case described by von Neuman involves a deterministic, i.e. predictable, evolution of the system. Physicist R.P. Feynman claimed that measurement has a purely random character. In this approach, it is possible to determine the probability of a certain value of the measured quantity. However, it is not possible to provide an accurate indication of the state of the system; you can only calculate mean values of ‘specific observables’ or determine the probability of such system moving to a certain state. Feynman stated also that the system with the highest probability moves along a classical trajectory, i.e. the one postulated by von Neuman.

According to the fundamental concept of quantum mechanics, i.e. the wave- particle duality, each micro-object is both characterised by a wave function and by particle-specific parameters such as mass that can be located in a particular state. Beside location, micro-objects are further characterised by quantum numbers that describe the micro-object’s energy states. The main quantum number n = 1, 2, 3, ... specifies stationary energy states static; orbital quantum number l (l = 0, 1, 2 ...) describes the micro-object’s momentum; magnetic quantum number m (m = 0, ±1, ±2 ...) specifies the orientation of the micro-object’s space; the spin quantum number describes the micro-object’s intrinsic an-

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[1] The Hilbert space is a unitary and complete space on which a scalar product has been identified. The completeness is a guarantee that each Cauchy string of elements is convergent to the elements of that space; furthermore, completeness means that while transitioning from one state to another it is impossible to go beyond the states that belong to the space at hand.

[2] Operator T is called Hermitian if for each x, y∈X, where X is a Hilbert space, the following is true: $(Tx|y)=(x|Ty)$; $(|)$ is a symbol for a scalar product.

gular momentum. The spin is constant for specific types of elementary particles. For example, particles with a spin of ½ are called fermions (electron, proton, and neutron) as opposed to bozons whose spins are equal to 1 (photons) etc. It must be added that no atom can have two or more particles with an identical configuration of the four basic quantum numbers.

One critical concept in quantum mechanics is the Planck constant. In classical physics, the energy of any system evolves continuously. This means its values can be anywhere near each other. In contrast, quantum mechanics allows energy to have only specific discrete values that are equal to the total amount of elementary portions of energy quanta ε_{v0}, $\varepsilon_v = k\ \varepsilon_{v0}$, $k = 0, 1, \ldots$ (Feynman et al. [4]).

The quantum theory is a generalisation of classical physics. It is a broader and more comprehensive theory applied in both in the realm of atoms and planets. It suggests that objects with great masses and but short wavelengths given the distances at hand can be examined in terms of their evolution using Newtonian mechanics or classical thermodynamics. Similarly, economic theory can assume that the space of goods or any other space composed of economic objects is, like matter, made up of small indivisible portions. These portions do not form regular networks but move in all possible directions (it could barely be argued that there is continuous evolution of the market prices of goods or stocks). The smallest unit of price change is one grosz, cent etc., or 0,01 of a currency unit (CU). Equally, it may be one gram, piece etc. Economic systems, including the 'small' ones, are subject to market cycles with their own length and amplitude, which makes them a perfect analogy to waves.

3.2 The Schrödinger equation and its applications in economics

Another key concept in quantum mechanics is system evolution. Systems can evolve in two ways. First, deterministic evolution as described by a unitary operator: states of the system change in a predictable manner. Secondly, random evolution upon measurement: the only prediction that can be made is the probability of the system finding itself in a given state. The wave function plays a critical role in quantum mechanics. Let $\Psi(x, y, z, t)$ be a wave function where x, y, z are location coordinates of an object in space $\Re^3$, and t is time. The square of function Ψ specifies the probability of the micro-object located at point with coordinates (x, y, z) at time t. Formally, $|\Psi|^2$ meets the following condition:

$$\Psi^*\Psi = |\Psi|^2 = p \tag{15}$$

where:

Ψ^* - is a dual wave function of Ψ,

p - is probability.

Effectively, it can be demonstrated that the probability of the micro-object finding itself in an element with volume $\Delta V = \Delta x \Delta y \Delta z$ of space equals:

$$P = p \cdot \Delta V = p \cdot \Delta x \Delta y \Delta z \tag{16}$$

By definition, the integral of the density of the probability throughout the volume of the space holding the object will equal 1:

$$\int_{\Re^3} |\Psi|^2 dV = \iiint_{\Re^3} |\Psi|^2 dxdydz = 1 \tag{17}$$

This, a wave function allows you to determine the probability of objects taking specific positions in a space. Consequently, it does not make sense to look for objects in locations where the square of the 'probability wave' amplitude modulus equals 0. Micro-objects will normally take fuzzy positions in a given portion of space and, since there are an infinite number of points in any small area, the probability assigned to each one of them cannot be a finite number (Feynman et al. [4]). In addition, the wave function provides a solution to a differential equation called the Schrödinger equation, expressed as follows:

$$i\hat{h}\frac{\partial \Psi}{\partial t} = -\frac{\hat{h}}{2m}\overline{\Delta}\Psi + U(x, y, z, t)\Psi \tag{18}$$

where

Δ - is the Laplace operator, i.e.

$$\overline{\Delta}\Psi = \frac{\partial^2\Psi}{\partial x^2} + \frac{\partial^2\Psi}{\partial y^2} + \frac{\partial^2\Psi}{\partial z^2}$$

m - is the mass of the micro-object, U(x, y, z, t) is the micro-object's potential energy dependent on its position,

$\hat{h} = \frac{h}{2\pi}$, h is the Planck constant ($h = 6{,}626 \cdot 10^{-34}$ J·s),

$i = \sqrt{-1}$ is the imaginary unit.

Additionally, it is accepted that function Ψ is finite, unique and continuous.

In case function U is not dependent on time $\left(\frac{\partial U}{\partial t}=0\right)$ the equation takes the following form:

$$\bar{\Delta}\Psi + \frac{2m}{\hat{h}^2}(E-U)\Psi = 0 \qquad (19)$$

where

E - is the kinetic energy of the micro-object.

The equation is solved by finding wave function Ψ and energy value E. There is no relationship to the distribution of potential energy that may be interpreted to affect the micro-object.

Economic systems are observed to be subject to market cycles. Hence, it is possible to ascribe wave properties to them. Further, they have their own mass (e.g. population of a country), as discussed in Section 2. The length of a wave related to market cycles is usually comparable to 'units' describing the mass of an economic system. Consequently, applying the rules of quantum mechanics in economics seems logical. It must be added that while he developed his equation for the micro-world, Schrödinger looked for inspiration in the macro-world, specifically on the propagation properties of light waves. Quantum effects become relevant where the object-related wavelength is comparable to distances, which is often the case in economic systems. Wave function can prove useful in forecasting as it allows to determine the probability of a certain object finding its way into a given area (x+Δx, y+Δy, z+Δz).

The Schrödinger equations could be applied for making projections of economic phenomena which evolve chaotically and do not follow a uniform curve, i.e. the system's evolution trajectory is an attractor, an often strange one (see e.g. Schuster [8]). Forecasting future values of such phenomena is fairly challenging. Only short-term forecasting is possible for strange attractors. Hence, instead of short-term projections it seems to make more sense to calculate the probability of a specific system findings itself in a given area (x+Δx, y+Δy, z+Δz), and this is feasible using the wave function. This method may be seen as an alternative to existing forecasting methods which are not always correct and may generate major inaccuracies.

The Schrödinger equation helps identify an 'area' in which the object is most likely to find itself in the future. An economic version of the equation is not easy but possible to construct. First, an equivalent to the Planck constant must b identified. If you examine a price or money related problem, the Planck constant may be 1 grosz, 1 cent etc. Depending on the problem at hand, it may be 1 gram, 1 piece etc. Secondly, if the trajectory of the economic system's evolution behaves chaotically the attractor related that trajectory should be spatially located and current coordinates should possibly be determined for the object's location. It does not make sense to search for future values of the phenomenon at hand outside the attractor area. Projections may use the 'closest neighbour'.

Presenting the Ψ wave function may be the hardest part. In fact, methods known in the world of physics may prove helpful in building such functions for economic models (see Feynman et al. [4]), p. 288-290 and 299-301). After you have dealt with the challenges of identifying all the variables contained in equation (11) you may take to trying to solve it, i.e. find the location of an area (x+Δx, y+Δy, z+Δz) (Δx, Δy, Δz → 0), for which the square of the absolute value of function Ψ is the largest. Such location will correspond to the best forecast of an economic phenomenon under study.

3.3 Schrödinger's cat paradox

The loss of the ability to forecast events while they transit from one state to another was described by Schrödinger in 1935. He presented a case of cat trapped in a box in which it may die as a result of electromagnetic discharge or it may survive. There is a fifty per cent chance of survival. Schrödinger claimed that according to quantum mechanics the 'state' of a cat in a box, before the box is opened, would be defined as both composed of a cat which is alive and dead, which can be expressed as:

$$|\Psi_{cat}\rangle = \alpha \mid \text{alive} \rangle + \beta \mid \text{dead} \rangle \qquad (20)$$

where

$$|\alpha|^2 + |\beta|^2 = 1$$

After the box is opened (i.e. after a measurement of the system is taken) an external observer would see either a living or a dead cat. This thought experiment may be taken to a higher level by placing an internal observer in a secure corner of the box. The observer would see the situation from within and track the cat's state immediately after the discharge that leads to the reduction of the state $|\Psi_{cat}\rangle$ to one of its constituents: $\mid \text{alive} \rangle$ or $\mid$

dead ⟩, which will express itself as the following states, respectively: $|\text{happy}\rangle$ or $|\text{sad}\rangle$. On the other hand, the external observer describes the system (containing the internal observer) using a linear superposition:

$$|\Psi_{cat} = \alpha_1 |\text{ alive }\rangle \otimes |\text{happy}\rangle + \beta_1 |\text{ dead }\rangle \otimes |\text{sad}\rangle \tag{21}$$

where $|\alpha_1|^2 + |\beta_1|^2 = 1$

The external observer will lead towards the reduction of the superposition only after the box is opened. In essence, the experiment points to the fact that while the cat is still a superposition of a dead-alive cat for the external observer (prior to opening the box) the internal observer is already happy at the cat's survival or sad at the cat's death.

3.4 The Heisenberg uncertainty principle and major formalisms of quantum mechanics

Another important law of quantum mechanics is Heisenberg uncertainty principle which says that it is not possible to determine two different physical quantities of a studied object at the same time with any accuracy. It is applied both in classical as in quantum physics, often in connection with the accuracy of measurement. In physics, measurement is process of interaction between the instrument and the object during which certain information about the properties of the latter is obtained. Measurement often affects the process and this can be used for assessing a number of phenomena.

The Heisenberg principle says that the product of errors (in the sense of standard deviation) while measuring two physical quantities is not bigger than the Planck constant (or its multiple). The following inequalities describe the principle:

$$\Delta x \Delta p_x \geq \hat{h}/2, \ \Delta y \Delta p_y \geq \hat{h}/2, \ \Delta z \Delta p_z \geq \hat{h}/2 \tag{22}$$

where

Δx, Δy, Δz - are the ranges of the object's locations,

Δp_x, Δp_y, Δp_z - are projections of momentum onto coordinate axes.

Symbols Δx, Δy, Δz, Δp_x, Δp_y, Δp_z mean root means squares of the deviation of coordinates and momentum projects from their mean values, i.e.:

$\Delta x = \sqrt{\langle \Delta x^2 \rangle} = \sqrt{\langle x^2 \rangle - \langle x \rangle^2}$, where $\langle x \rangle$ is a physical symbol of a mean quantity.

It follows from Heisenberg's relation (22) that the product of the uncertainty of the measured momentum and the micro-object's location is never smaller than the Planck constant. The uncertainty principle may further be applied to energy and time. If a micro-object's energy is E then the accuracy of energy measurement ΔE will depend on the time of measurement ΔT, as in the inequality:

$$\Delta T \Delta E \geq \hat{h}/2 \tag{23}$$

Inequality (23) says that the product of the uncertainty of the time an object remains in a certain state and its energy are not bigger than Planck constant. The energy of a micro-object which remains in a stationary state is precisely specified and it equals $\Delta E = 0$.

Similar relations are found in classical physics in the description of a macro-scale wave movement. In general terms, the product of the uncertainty of a pair of canonically coupled quantities (e.g. $[p_x, x]$, $[T, E]$ are canonically coupled) is not smaller than Planck constant.

The uncertainty relations with respect to location and momentum stipulate that no object can simultaneously have accurately specified coordinates and related momentum constituents. This property means that the concept of a micro-object's trajectory in phase space is losing in importance as it is not described by any time-parameterised and 'strictly specified' line but rather by a fuzzy area. Similarly, the trajectory of a large number of economic phenomena evolves chaotically.

3.5 Major Theories of Quantum Mechanics and Differences Between Classical Physics and Quantum Mechanics

To summarise, here are the main formulations of quantum mechanics:

1) A state function must be used for the description of any system.
2) A physical system is in a certain state with a certain probability.
3) For each dynamic quantity a form of description is used and it is called a linear operator.
4) State functions fulfil a state-specific Schrödinger equation.

5) Every physical object is characterised using a wave function. One property of the wave function is that its root square is the probability of the object at hand having a specific spatial location.
6) A quantum object exhibits all the properties of a particle (mass) and a wave (frequency); it is represented by states which can be characterised using quantum numbers.
7) Quantities that characterise a quantum object, for example energy, do not have a specific value at a certain point in time but are characterised by a set of possible own values which can be calculated using Schrödinger equation.
8) The uncertainty principle is a consequence of the lack of commutation of canonically coupled operators such as location or momentum.

Note:

- a commutator is an operator which gives an indication to what extent matrix multiplication or operations of operators fail to be communitative, i.e. $[A\ B] = AB - BA \neq 0$,
- in quantum mechanics, operators that define physical quantities (observables) do not have to be commutative.

To sum up, differences between classical and quantum physics are significant. The classical theory says specifically where a given micro-object is located at a given point in time, or what its trajectory is. However, there is no experimental proof or disproof of such calculations. The quantum theory does not say anything about a specific location of a micro-object in space. Instead, it makes a projection of the probability of the micro-object's location at a point in time.

The superiority of quantum over classical physics is that its projections are confirmed by experimentation. Furthermore, classical physics says that 'all things physical' can be measured with any accuracy. In contrast, the Heisenberg uncertainty principle can be interpreted as a formulation of limits to accuracy. Classical physical methods cannot be helpful in recreating reality because reality is more than a set of defined elements.

3.6 Suggested applications of certain quantum mechanics principles in social sciences

The uncertainty principle is a universal law which can be applied in a number of disciplines. We believe it can also be applied in social sciences. The observation of economic processes appears to be an insufficient method of measuring and quantifying such phenomena, let alone making decisions under such uncertain conditions. Researchers use various statistical methods and mathematical models based on such formalisms as neuron networks, genetic algorithms or the theory of chaos. These methods return approximate results. For example, the interpretation of statistical data is affected by the method of data collection, data quantification or thought experiment planning, sampling, eliminating distortions or uncontrolled variables and many other factors. Similarly, neuron networks, though capable of learning and generalising knowledge, are nothing but approximations. In this case, approximations are even greater and contradicting signals may generate contracting decisions.

On the other hand, genetic algorithms emulate evolution. They test certain rules and select a set of such rules which optimise a given function. In order to make predictions based on genetic algorithms it is essential that a large body of input data should be collected, which is not always feasible and mistakes can be made at a very early stage of a research project.

The theory of chaos relies on the principles of the evolution of deterministic systems which may behave chaotically in certain situations. They are normally non-linear systems and most of them cannot be precisely described, particularly if they relate to economic situations. While it is possible to apply Takens' delay embedding theorem the use of another approximative method makes the uncertainty of decisions or conclusions even greater.

To sum up, data collection, statistical and predictive methods are equivalents of measurement in physics. Overlapping approximative results generate a number of errors which cumulatively lead to a bias which is not smaller than a certain constant quantity that characterises the phenomenon at hand. This constant may be interpreted as an economic constant equivalent to Planck constant. Indeed, it may be Planck constant under certain circumstances (see Section 4).

There are more general considerations with regard to the application of quantum mechanics formalisms. According to Stapp H., the universe, and everything in it, may be presented as a universal wave function which evolves in time according to Schrödinger wave equation and determines the probabilities of events.

In other words, every alternative option is represented by an evolving wave function[3].

Schrödinger equation is believed by many physicists to be a nearly ideal representation of quantum physical phenomena and can prove a good predictive tool in social sciences. Notably, Schrödinger construed his equation using existing laws of the macro- rather than micro-world. He used the properties of heat waves and focused on issues linked to turbulence. The equation has been applied on numerous occasions, e.g. in atomic and hydrogen bomb programs.

The following section will seek analogies between the classical auction model and quantum mechanics laws.

4 Analogies between the rules of English auction and the laws of quantum mechanics

Auctioning is one of the oldest method of exchanging goods and currency. They are economic mechanisms designed to effectively allocate goods and money through bidding. Auction rules are normally predefined, which means they can be interpreted as the rules of the game, the game being the auction itself. Normally, the winner of an auction is the buyer, a player who offers the highest price for the auctioned goods. Auctions are mainly used for non-homogenous and unconventional goods, services and other benefits.

There are many types of auctions and they are usually classified by the form of delivery and method of transacting business. There are oral and written auctions. Oral auctions include English auctions, where participants present their price bids in an ascending order. The auction ends when the price is so high that no other bidder can 'outbid' and the bidder offering the highest price wins.

Another oral type if the Dutch auction where the price of a good is effectively reduced until a buyer is found. This type of goods and money allocation is used by second-hand shops and for selling perishable goods. Written auctions include first and second dealed bid auctions. The first dealed bid auction, also known as first-price sealed-bid auction (FPSB) is a process where bids are place in writing, e.g. in sealed envelopes. The highest bid wins and the price of goods paid by the buyer is equal to the bidding price. The second dealed bid auction, also known as Vickrey auction[4], is a process where the highest bid wins but the price paid by the buyer is the second highest.

There are other types of auctions and new types are being developed. The auction theory is one of the most vibrant areas of research combining economic and games theory formalisms. New mathematical auction models are based mainly on the games theory (see Drabik [3]). These models utilise the classical probability calculus. However, it often proves insufficient in addressing the nuances of auctioning. Therefore, attempts will be made to describe auctioning in the language of quantum mechanics. The main focus will be to present analogies between auction rules and quantum mechanics laws.

Without loss of generality, it can be assumed that buyers act rationally, which means they will stop short of buying goods above a predefined resignation price (a price of their own choice). Furthermore, it can be comfortably assumed that "purchase" and "sale" are equivalent concepts because selling goods also means buying money.

Let us consider an English auction with N buyers (players 1... N) and one seller (player 0). Let $|\Psi\rangle^5{}_k$ be the vector of Hilbert space uniquely identifying the strategy or state of the k^{th} buyer. Function $\Psi(x) = \langle x|\Psi\rangle$ defines the amplitude of the probability of wave function Ψ. According to quantum theory, as briefly summarised in Section 3 above, it is accepted that the root square of probability amplitude modulus $|\langle x|\Psi\rangle|^2$ is the density of the probability of the measure of quantity x of random variable X representing the state of the system.

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[3] This is quoted after A. Scott (1999), *Schody do umysłu* (*Stairway to the Mind*), WNT Warsaw. This book is not listed in references because it has not been used in this publication. However, it is entirely dedicated to applications of quantum mechanics in biology.

[4] William Vickey received a Nobel prize in economics in 1994, inter alia for his work in the area of auction theory.

[5] Strategies $|\Psi\rangle_k$ (k = 1,... N) are elements of Hilbert space H. Formula $\langle|\rangle$: $H\times H \to C$, known as a scalar product for any Ψ, Ψ', $\Psi''\in H$, $\lambda\in C$ has the following properties:
1) $\langle\Psi|\Psi\rangle \geq 0$,
2) $\langle\Psi|\Psi\rangle = 0 \Rightarrow \Psi = 0$,
3) $\langle\Psi|\Psi'+\Psi''\rangle = \langle\Psi|\Psi'\rangle + \langle\Psi|\Psi''\rangle$,
4) $\langle\Psi|\lambda\Psi\rangle = \lambda\,\langle\Psi|\Psi\rangle$, 5) $\langle\Psi|\Psi'\rangle = \langle\Psi'|\Psi\rangle^*$, where the asterik denotes entaglement.

Since Hilbert space is the major formalism of quantum theory the probability amplitude should be standardised to 1 according to the following formula (Piotrowski [8]):

$$\langle q|\Phi\rangle_k = \frac{\langle q|\Psi\rangle_k}{\langle\Psi|\Psi\rangle_k} \quad (k = 1,\dots N) \tag{24}$$

where

$$\langle\Psi|\Psi\rangle = \int_{-\infty}^{+\infty}\Psi(x)\overline{\Psi(x)}dx$$

Expression (24) defines a standardised amplitude to the strategy that defines the commitment of the k^{th} buyer to purchase the goods at price q. Expression:

$$\langle p_{in}|\Phi\rangle_0 = \frac{\langle p_{in}|\Psi\rangle_0}{\langle\Psi|\Psi\rangle_0}$$

is the seller's (player 0) commitment which is to specify reservation price p_{in}, i.e. to specify a price under which the goods must not be sold. Reservation price p_{in} is a measurement concept.

According to quantum mechanics formalisms, the density of the probability of a specific value of a random variable which characterises the k^{th} auction participant (player k) is equal to the root square of the modulus of a strategy standardised to one:

$$P_k = |\Phi_k|^2 = \frac{|\langle q|\Psi\rangle_k|^2}{\langle\Psi|\Psi\rangle_k} \tag{25}$$

The auction is won by the k^{th} buyer if his/her price is the highest which makes the probability of reaching state Ψ_{out} the highest as well. Thus:

$$\frac{|\langle q_1|\Psi\rangle_{out}|^2}{\langle\Psi|\Psi\rangle_{out}} \le \dots \le \frac{|\langle q_k|\Psi\rangle_{out}|^2}{\langle\Psi|\Psi\rangle_{out}}.$$

The equality sign means that strategies of auction participants may be entangled. In quantum theory, entanglement means a certain form of a correlated quantum state of two or more particles or other quantum systems. In other words, entangled quantum states provide an indication of an existing correlation between states despite the lack of proximity. The assumption of a single buying and selling price in auction theory is equivalent to the entanglement of quantum phenomena.

Bidding is process of dynamic transitions from one state to another or bidding higher and higher prices by buyers:

$$\langle\Phi_{in}|\Phi_{out}\rangle = \sum_i \langle\Phi_{in}|q_i\rangle\langle q_i|\Phi_{out}\rangle,$$
$$(q_1 \le q_2 \le \dots \le q_k) \tag{26}$$

where q_i means price bid by the i^{th} buyer. It can be assumed they correspond to base states e_i, $e_i e_j = \delta_{ij}$ and $\langle i|j\rangle = \delta_{ij}$.

Note:
According to quantum mechanics, a transition from state $\aleph$ to state $\Im$ may be expressed as a sum after the system of base states of the product of amplitudes of transition from state $\aleph$ to the following base states up to state $\Im$:

$$\langle\aleph|\Im\rangle = \sum_i \langle\aleph|i\rangle\langle i|\Im\rangle.$$

The transaction is complete if one of the buyers (k^{th}) bids an amount which is not topped up by any other auction participant and pays for the goods not more that the resignation price. This is now the player wins the auction. Buyers 1, ... k-1 ($k \le N$) drop out from the auction because having bid too low a price they fail to reach the final state Φ_{out}. – in accordance with Pauli exclusion principle there is no free space for them there. The Pauli principle says that no two micro-objects can be in the same state at the same time. The principle is responsible for the stability of matter. For auctions, it is responsible for an uninterrupted process.

Thus, a transaction really means a transition from the states of initial strategies adopted by participants

$$|\Phi\rangle_{in} \text{ to final state } |\Phi\rangle_{out}.: |\Phi\rangle_{in} = T\,|\Phi\rangle_{out} \tag{27}$$

where

$$T = |p\rangle_{in} + \sum_{ij}\langle q_i|i\rangle\langle i|T_A|j\rangle\langle j|q_j\rangle$$

is transaction operator,

$|p\rangle_{in}$ - is the asking or reservation price,

T_A - is an inter-state transition operator,

q_i - is the price offered in bidding.

Buyers often lack the ability to put a specific value on an item of goods (specify the price at which they would give up the purchase).

The price may evolve as a result of information continuously received by the buyer. This situation corresponds to the Heisenberg principle. For English auctions with numerous buyers, the Heisenberg principle may be formulated as follows: the product of two dispersion measures - purchase and sale - may not be smaller than Planck constant. Planck constant h corresponds to the lowest risk appetite of the player. This principle holds for any pair of players (i, j), *ipso ergo:*

$$\Delta q_i \Delta q_j \geq c \cdot h \quad (i \neq j,\ i, j = 0,1,...., k)$$

where c is a certain constant, $c \geq 0$.

In addition, a rational strategy known from auction theory, which is not to bid a price above your own valuation: $\langle q|\Phi\rangle_i \leq \langle q|v_i\rangle$, where v_i is goods valuation of the i^{th} bidder is also in line with the Heisenberg uncertainty principle.

Many more similar analogies can be found. At least one more deserves increased attention - the Schrödinger's cat paradox, as outlined in Section 3.3.

The seller's state (k = 0) immediately before the transaction is closed (prior to measurement) can be expressed in the following form:

$$|\Psi_0\rangle = \alpha\,|\text{ transaction closed }\rangle + \beta\,|\text{ transaction fails }\rangle \qquad (28)$$

where $|\alpha|^2 + |\beta|^2 = 1$.

The state of the k^{th} (k = 1, 2,... N) buyer is characterised as follows:

$$|\Psi_k\rangle = \alpha_1\,|\text{satisfied with transaction}\rangle \otimes |\text{transaction closed}\rangle + \beta_1\,|\text{ uncomfortable with transaction failure}\rangle \otimes |\text{transaction fails}\rangle \qquad (29)$$

where $|\alpha_1|^2 + |\beta_1|^2 = 1$

It may be observed that the states described by formulae (28) and (29) correspond to 'diagnoses' of the external and internal observers in the Schrödinger's cat paradox. When an auction is completed the outcome state $|\Psi_k\rangle_{out}$ is reduced to state: $|$transaction completed$\rangle$ or $|$transaction fails$\rangle$, but no doubt the k^{th} buyer (k = 1,... N) fees $|$satisfied$\rangle$ when he/she succeeds in purchasing the goods on favourable terms or feels $|$uncomfortable$\rangle$.

5 Conclusion

The modelling of economic phenomena based on quantum theory provides more precise descriptions than using the classical probability calculus. In addition, there are a number of analogies between quantum mechanics and social sciences. In both cases, finding the precise 'location' of an object requires taking numerous measurements (identifying waves of different frequencies).

This is the only way, with a high degree of uncertainty, to identify a more or less precise location of an object. A non-zero correlation the variables corresponding to specific economic phenomena proves their dependencies which may be compared to the concept of system entanglement in quantum theory. It is further understood that the evolution of a quantum system 'is determined' by the unitary operator affecting any given state at a point in time.

A similar role is played by the transaction operator in auction theory, as expressed in formula (17). The uncertainty and inaccuracy inherent to the description of a broad range of economic phenomena are not caused by the failure of statistical and forecasting methods but are inherent to such phenomena themselves.

A similar situation is found in quantum mechanics - the complicated nature of phenomena plays a bigger role than the accuracy of measuring instruments. Consequently, both social and physical phenomena may only be described (identified) in approximative terms under the uncertainty principle.

A market described with the use of quantum mechanics tools is likely to multiply its closed transactions. For example, one can multiply profit by holding several auctions simultaneously. The Pauli exclusion principle does not prevent participation in other auctions. By applying a certain (well designed) strategy in a number of places at the same time does increase the probability of profit, which has recently been so evident in online auctions.

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THE FUTURE OF BLUE ECONOMY: LESSONS FOR EUROPEAN UNION

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Abstract: Advancing global economic integration through the oceans, an interplay of economic, social, climatologic and technical forces are bringing the oceans to the forefront of resource development and business activity. With oceans covering over 70 percent of the Earth's surface, the future of the ocean space is increasingly being shaped by the interaction of numerous and powerful forces, most important of them being human activities. Over next 20 years, increasing uncertainty will be generated by the confluence of rapid social, cultural, technological and geopolitical changes. The rapid global increase in the production outputs of industry, agriculture and fisheries, as well as rising levels of consumption of marine products and the demand for coastal space worldwide is exerting increasing environmental pressure on the ocean. There is a need to identify more effective means to reduce the environmental impacts generated by the economic growth and its by-products. Sustainable approaches meet the needs of present without compromising the ability of future generations to satisfy their own needs. The Blue Economy concept is about the commercial development of oceans in a sustainable way. Poland's future economic security is linked with country's presence in the world ocean and successful membership in international bodies such as European Union, NATO and various United Nations maritime organizations. These factors will also determine Poland's place and its role in the global ocean economy.

Key words: Oceans, Blue Economy, sustainability, marine resources, European Union, ocean uses, marine policy.

1 Introductory remarks

It is a new lens for thinking about ocean industries that are more connected to each other than they seem now but also that sustainability needs to be a filter for every use of the ocean from tourism and marine recreation to resource mining and aquaculture. Ocean-related business opportunities are far ranging and significant. They are related to transportation, production of seafood, ocean energy, extraction of minerals, biotechnology, human settlements, tourism and recreation and ocean exploration. The Blue Economy industry is now emerging, in a way that is analogous to the evolution of the "outer space industry" that developed over the past 50 years.

New opportunities created by globalisation and increasing role of oceans in economies of many maritime nations are calling for a new effort by the European Union to promote research, investment, and other business activities that could generate new opportunities and benefits for the member-states.

Poland is the country with sizable maritime traditions and achievements ranging from training of skilled marine specialists, through shipbuilding, fisheries, marine tourism to marine transportation and ocean exploration. By joining most advanced maritime nations of the world and the European Union, Poland could create a long-term conditions for increasing involvement in the ocean economic activities. They could generate additional supplies of energy, seafood, ocean minerals and open new opportunities created by the international sea trade.

The future use and benefits that world oceans offer to individual countries is dependent on the investments in infrastructures, preparation of specialists and commitment of each society to tie up its future with the healthy ocean environment. A broad range of ocean uses can be mapped into a small set of ocean resources. These resources include ocean space important for transportation of goods and people, living resources and their habitats, sea bottom minerals and energy. Many countries pursue the goal to occupy a ranking position in the process of integration with the world marine economy.

When valuing achievements resulting from human interactions with the oceans during the last century, we are looking with increased confidence and interest on possibilities that are opening for us by quickly progressing economic interdependence that oceans promote in a global context. From the European Union's perspective these tendencies create a need of increased attention toward the principles of sustainability and mobilization of collaborative actions of the Union's maritime and land-locked nations.

These principles call for harmonious use of marine resources including development of shipping, production of off-shore energy, extraction of minerals, coastal and distant – water fisheries, mariculture and the marine tourism[1].

By entering on the sustainable path of ocean development we could strengthen the long-term links of the national economy with the marine and coastal environment bringing us closer to the vast resources of the World Ocean. Such orientation would also have a strong impact on the future marine policy of European Union and its member-countries.

The concept of environmentally friendly use of the ocean resources allows to evaluate how new technologies and models of the commercial activity can meet environmental and economic conditions of the sustainable use of the ocean resources[2].

This approach helps to meet obligations and gain benefits by European countries that are resulting from increasing technological potential, membership in European Union and their growing responsibilities as members of international organizations dealing with the use and management of the ocean space.

This paper has two major objectives:

- First, is to demonstrate that the sustainable approach to the ocean uses is an imperative that could assure long-term benefits for the world community that ocean can generate with their vast resources.
- The second objective is to show that the modern ocean technology is opening new frontiers that could generate significant benefits for those who are willing to undertake an effort to apply these achievements in the ocean resource use.

On this background it might become evident that concerted effort and harmonized initiatives by countries interested to take advantage of these opportunities are prerequisites of the successful and sustainable development of the ocean resources. This approach is addressed as the third objective of the study.

2 New ocean opportunities and challenges

In order to better understand the role of oceans in the future of European Union we must consider increasing convergence of environmental, economic, social, and technical factors that are bringing greater opportunities that are offered by the world's oceans: in transportation, food production, energy, mineral extraction, biotechnology, human settlement in the coastal zones, tourism and recreation, and the scientific research.

A closer look at these factors allows us to distinguish a number of opportunities that ocean resources create for the benefit of the global economy. These include:

2.1 Development of bioscience

The XX century was defined by scientific advances in physics and electronics. Advances in biology and life sciences will define the XXI century. Synthetic biology will help us create new microorganisms to accomplish specific tasks, such as cleaning toxic waste, producing bio-fuels, and healing our bodies. In the world of biology, genetic data is like gold, and the oceans contain the vast bulk of the earth's genetic diversity.

Biotechnology pioneer J. Craig Venter has conducted the most comprehensive survey of marine genetics to date[3]. His and similar works represent first steps toward understanding and economically exploiting the genetic treasury of the sea.

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2.2 New sources of protein

Human activity is often blamed as a main contributor to the global environmental change. However, if that activity disappeared tomorrow, agricultural production would continue to warm the planet. Simply put, protein production through meat is highly inefficient; in fact, an estimated 800 million people could survive on the grains fed to livestock in the Unites States alone[4]. Rising demands for animal protein in developing economies, and the need to reduce carbon emissions are now on a collision course. One way to avoid this conflict is to develop new sources of protein from the most efficient means known today - fish farming - which is forecasted to overtake global beef production by the first decade of the XXI century[5].

2.3 Transition from fossil fuel to renewable energy

Growing energy demand and declining reserves of oil and natural gas will force a massive transition to renewable energy sources in the coming decades. As a vast reserve of kinetic and thermal energy, the world's oceans represent a huge untapped source of the wind, thermal, kinetic and other forms of the renewable energy.

2.4 Mineral wealth

The oceans contain vast quantities of vital minerals. However, direct extraction of resources is limited today to salt, magnesium, placer gold, tin, titanium, diamonds, and fresh water. However, mineral extraction in marine areas is expected to begin long before land deposits become exhausted because of issues surrounding land-use priorities, clean water requirements, and environmental considerations.

Figure 1. Major concentrations of manganese nodules in the World oceans
(source: NOAA, 2006)

Technology to extract these minerals economically is being developed, and policies for ocean mining will need to be considered[6].

Constraints on those extractions are nearly always economic, but are also affected by ownership, transportation distances, and technological challenges (e.g., the depth of ocean basins). Increasing human populations and the exhaustion of economically accessible terrestrial deposits, however, will undoubtedly lead to increased extraction from the bottom of world's oceans.

At depths between 4,000 m and 6,000 meters developing mining and processing technologies are needed to recover the desired minerals from the nodules - nickel, copper, cobalt, and manganese - but these require large investments.

One enterprise is now in an advanced stage of preparatory work for extracting hydrothermal minerals from the deep trenches of the Red Sea. Despite the rather dismal mineral market conditions, we will become more dependent on the oceans as a mineral resource reservoir in the future.

[4] Pimentel D. - *US could feed 800 million people with grain that livestock eat*. College of Agriculture and Life Sciences, Cornell University, Cornell News Service, Press Release, August 7, 1997, http://www.news.cornell.edu/releases/aug97/livestock.hrs.html

[5] Brown L.R. - *Fish Farming May Soon Overtake Cattle Ranching As a Food Source, Plan B Updates*. Earth Policy Institute, Washington, D.C. October 03 2000, http://www earthpolicy.org/Alerts/Alert9.htm

[6] *MMS Minerals Management Service, Ocean Energy and Minerals: Resources For The Future*. Year of the Ocean 1998, Washington, D.C., 1999, http://www.yoto98.noaa.gov/yoto/meeting/energy_316.html

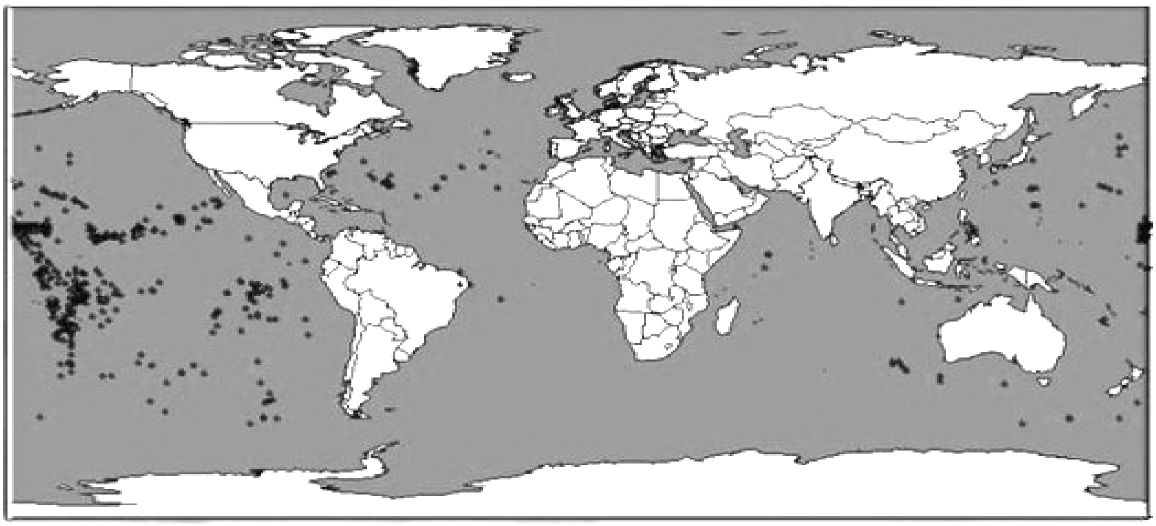

Figure 2. Major concentrations of manganese nodules in the World oceans
(source: NOAA, 2006)

2.5 Factors affecting the future of marine transportation

Decade on decade, seaborne trade has continued to grow and, with the world's population predicted to continue to raise, the demand for shipping can only increase.

The reality is that, in good times and bad, in today's global economy, hundreds of millions of people all over the world rely on ships to transport the great multitude of commodities, fuel, foodstuffs, goods and products on which we all depend[7]. Inevitably, there has been considerable focus on piracy, which, apart from being a threat to trade, has a direct, significant and very personal impact on the seafarers involved. It is a source of great concern, and a genuine anathema in the 21st century that the threat of piracy and armed robbery against international shipping is as pernicious today as at any time in history.

Marine transportation, international sea trade and globalization will follow the economic development that results from increased consumption of products and services mainly in industrialized countries' markets. The future of marine transportation will be affected by economic crisis but also by safety of communication lines free of terrorist and piracy challenges.

Demographic changes and shifts in valuing different commodities, services and consumption methods as a result of dematerialization of the social culture. The demand for transportation services will generate new environmental threats that must be removed by ship owners and international organizations along the lines set by the sustainable, "Blue" economy[8].

2.6 Coastal urbanization

Nearly 40 percent of cities larger than 500,000 are located on the coast[9]. Coastal cities deplete nearby areas of water, beaches, dunes, fish resources and mangrove forests, rendering them less capable of supporting land areas and rural populations thus adding to the pressures for urban migration.

Burgeoning cities are expanding into fragile ecosystems. Air pollution already exceeds health standards in many mega cities in developing countries. Sewage and industrial effluents are released into waterways with minimal or no treatment, threatening human health and aquatic life. Some urban environmental problems such as access to safe drinking water improve with economic growth, while others tend to worsen.

[7] Mitropoulos E.E. - *The future of shipping: contemporary challenges*. Special Lecture, International Maritime Organization, London, October 15, 2010.

[8] Corbett J.J., Winebrake J. - *The Impacts of Globalization on International Maritime Transport Activity: Past Trends and Future Perspectives*. OECD/ITF Global Forum on Transport and Environment, Guadalajara, Mexico, November 10-12, 2008.

[9] *The State of African Cities 2008, A framework for addressing urban challenges in Africa.* UN Habitat Program, United Nations Human Settlements Programme, Nairobi, Kenia 2008.

Thus in the absence of policy reform, stronger institutions, and enlightened political leadership, economic and population growth in developing countries in the near term may lead to a deterioration of the urban environment, both physical and social. Stresses on the global environment from urban activities are also likely to accelerate. Rural areas throughout the developing world are being depopulated as people flock to prosperous coastal cities. These urban centers contribute to deterioration of the coastal ecosystems by landscape modification and pollution.

2.7 Expanding marine tourism and recreation

Marine tourism is the most dynamic area of human activities on the oceans and it is developing quickly during more than last 25 years. The newest tendency is the cruising tourism that is now entering into its sustainable phase of development. In 2008 contribution of the cruise industry to the American economy was US$ 40 bln.

Approximately 9 million passengers boarded cruise ships in the US ports. This is about 70% of the tourism-related boarding's in the world[10].

3 The Twenty-First Century Response

3.1 Sustainable approach to the ocean development

Many enterprises and governments understand that healthy oceans lead to greater productivity, higher quality, and sustainable long-term growth. This understanding stands in contrast to the ways in which companies and governments have treated oceans in the past. Instead of seeing oceans as teeming wildernesses to be exploited, the sustainable marine economy takes a 'systems' approach: it views oceans as fertile gardens that must be carefully managed from one generation to the next. It considers the down-stream impacts of economic exploitation - both positive and negative - on the total system[11].

Several factors shape this view:

- the spillover of 'green' values and business practices from land-based economies,
- scientific understanding of the fragility of the ocean ecosystems and the great value ocean ecosystems provide, and
- new tools for managing common resources, examples include regulation of marine protected areas and transferable fishing quotas.

The sustainable development approach is firmly rooted in the ecological health and resilience of marine ecosystems. Unlike conventional green strategies that seek to minimize or mitigate the negative impacts of industries on air, land, and water, new strategies aim for more; they aim to leave the environment better than they found it through cleaner effluent streams, increased biodiversity, better scientific data, etc. This "better than neutral" approach will be a challenge for existing firms in that it sets a new, high level standard of performance.

Ecological economics will be a vital tool in moving ocean industries towards new standards of sustainability. This cross-disciplinary field is developing models and measurements for valuing the services that ecosystems provide, and provides a framework for defining what is and is not a profitable business.

Ecological economics builds the cost of environmental degradation into its markets. As more of these external costs are internalized as firm costs, Blue companies will be more economically viable.

3.2 New opportunities and challenges

What are we likely to see as ocean space industry develops? Early evidence points to new physical structures, a new age of oceanography, a gradual influx of profit-seeking enterprises, and an attempt to develop shared responsibility for the stewardship of ocean resources.

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[10] *The Contribution of the North American Cruise Industry to the U.S. Economy in 2008*. Prepared for: Cruise Lines International Association by Business Research & Economic Advisors, June 2009.

[11] There are many examples of negative impacts human activities hale on the natural environment. For example, pollution of the marine waters, chemical threats caused by the aquaculture, or agricultural pollution brought to the sea by rivers from fields enriched with artificial fertilizers used on produce corn needed to produce ethanol. These contaminants are introduced to the environment thousands of miles away in the hinterland but in the final analysis they reach the rivers and are brought to the seas causing massive destruction of marine fauna and flora.

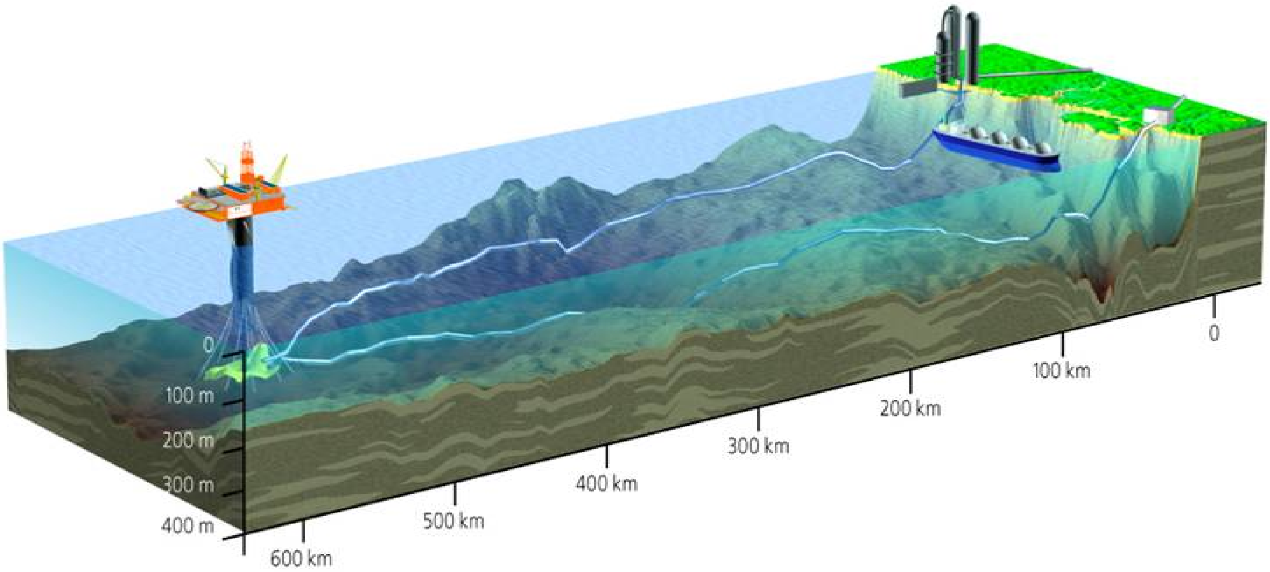

Figure 3. Investment plans to exctract gas from the bottom of the Shtockman Field (Russian Arctic) by French TOTAL and Norwegian Stat-Oil companies
(source: Moe A. [8])

A convergence of environmental, economic, social, and technical factors is bringing greater attention to the opportunities available in the world's oceans: in transportation, food production, energy, mineral extraction, biotechnology, human settlement in the coastal zones, tourism and recreation, and scientific research.

3.3 Emergence of an ocean space industry

The intersection of the macro global trends (energy transition, the search for new sources of food and mineral resources, etc.), and new frameworks for ocean sustainability, is leading to the emergence of an 'ocean space' industry. Early indicators of such a future industry can be seen today in a growing network of firms and sectors that share Blue economy characteristics.

There are some parallels between the early aerospace industry and the ocean space industry now developing. Aerospace emerged from a blurring of the boundary between aviation and space travel. Many of the technologies and applications found in one domain were found to be applicable in the other. Also, many of the customers and suppliers were the same.

Aerospace benefited from materials, computing, communication, and other technologies developed by contractors for military use in extreme environments. The same is bound to happen as commercial firms seek opportunity in the world's oceans.

Ocean space, like aerospace, is challenged by the extreme nature of its environment. Corrosion, tides and powerful currents, biological infiltration, poor visibility, communication difficulties, and severe weather present enormous challenges to reliable and efficient operations in marine settings.

3.4 Migration of enterprises

Finally, as the economic value of ocean space is more widely recognized, business enterprises will allocate more resources toward it treating ocean space, in effect, as an adjacent market. Just as Boeing and Lockheed leveraged their aircraft design and manufacturing capabilities toward space vehicles, we are likely to see ship construction firms develop expertise in offshore structures. As their undersea reserves dwindle, offshore oil drillers, who already have substantial ocean space operations, may direct some of their cash flows into ocean bio-fuel R&D and other oceanic ventures. This natural migration will occur as companies seek to expand with their own value chains.

4 New directions of the World ocean industry

4.1 Oceanographic research

The first age of oceanography began in the 1950s and 1960s, as the seas became a stage for Cold War submarine operations. Today, advances in undersea sensor networks, computer modeling, biological diagnostics, data archiving, and international collaboration are igniting a new age of oceanography. Cold War scientific institutions such as Scripps and Woods Hole are leveraging their deep knowledge and technical competencies to new research missions at sea. They, the Monterey Bay Aquarium Research Institute, and other organizations are expanding our understanding of the vast undersea frontier[12].

4.2 Ocean-scale engineering and design

Skyscrapers, superhighways, dams, and power grids mark man's industrial conquest of the land. Commercial jetliners, the Space Shuttle, satellites, and the International Space Station highlight man's attempts to tame the aerospace frontier. In this century, a growing number of engineering and design projects are looking seaward.

The massive coastal engineering of Dubai is a prime example, and MIT Sea Grant's proposal for migratory fish farms point towards a grand scale of human activity in the world's oceans. These will be the initial physical landmarks of the Blue economy.

4.3 Ocean policies of major maritime countries

Major maritime countries in the world come to recognize the importance of development of marine and ocean industries for their future prosperity. They seek to secure sustainable future by carefully managing and conserving marine resources, which are relatively abundant but finite. Table 1 summarizes key directions of the marine policy of several most important maritime nations, who have adopted principles of the Blue economy.

[12] Joroff M. - *The Blue Economy: Sustainable industrialization of the oceans* [at] Proceedings, International Symposium on Blue Economy Initiative for Green Growth, Massachusetts Institute of Technology and Korean Maritime Institute, Seoul, Korea, May 7, 2009, pp. 173 -181.

5 International maritime interests of new EU member-states

5.1 European integration and Poland's partner ships

New members of the European Union are facing important challenges of a rapid globalization and changes resulting from current ocean policy of the European Commission. International maritime interests of this group of countries must, therefore, be considered not only in the sub-regional (Central Europe) or Union's perspectives but also considering global ocean opportunities.

Similarly as it was during the period of joining NATO and EU, opening to the global ocean will require intensive cooperation between the private sector, the Government and with the European Commission. Additional challenges are obligations resulting from Poland's membership in other European organizations, maritime relations with European states and transatlantic partnership with the United States. This is particularly important in the straggle against threats of international terrorism and militant radicalism.

5.2 International maritime policy of European Union

Economic development of the majority of industrialized countries, including those in European Union, has its reflection in the growing market demand and consumption. Both factors are acting as driving forces of maritime investments overseas, especially in securing an access to the sources of energy and protein of the marine origin.

The European Union represents and defends overseas maritime interests of such countries as France, Spain, Portugal and Italy. The European Union's aid programs for the coastal nations of Africa, Latin America or Pacific and Indian Ocean island states is frequently combined with subsidies for European companies striving to gain an access to the marine resources of developing countries[13]

[13] Kaczynski V.M., Fluharty D.L. - *European policies in West Africa: Who benefits from fisheries agreements?* [in] Marine Policy Journal, No. 26, 2002, pp. 75-93.

Table 1. Marine policy directions adopted by major nations
(source:[14])

Country	Major policy directions/measures	Source:
USA	Promotion of ocean education Economic growth and resource conservation along the coast Coastal and ocean water quality preservation Enhancement of the use and protection of ocean resources Advancement of ocean-related science and technology U.S. participation in international maritime policy	An Ocean Blueprint for the 21st Century (2004) U.S. Ocean Action Plan Implementation Update (2007)
Japan	Development and utilization of ocean resources Preservation of ocean environment Development of exclusive economic zone (EEZ) Securing shipping transportation Ensuring marine security Carrying out ocean-related R&D and survey Development of marine and ocean industries Integrated management of coastal area Conservation of remote islands Enhancement of international cooperation Enhancement of international cooperation Maritime education	Japan's Ocean Master Plan (2008)
Canada	International leadership, sovereignty and security Integrated ocean management for sustainable development Health of the oceans Ocean science and technology development	Ocean's Action Plan (2005) Technology Roadmap Special Report: Thinking beyond our shorelines (2005)
China	Enhancement of people's awareness of the importance of ocean Securing ocean related rights Conservation of ocean ecosystems Development of ocean resources Integrated governance of ocean	11th 5-Year Plan (2006-2010) Report on Marine and Ocean Industries Development in China (2006)
Korea	Creation of a clean/secure ocean environment Promotion of the global business and infrastructures for ocean explorations Protection of the marine environment Establishment of Northeast Asia shipping/logistics hub Sustainable development and construction of the fishery industry infrastructures Securing stable supplies of the fishery products Development of oceanographic research and extraction of the marine resources Training of the marine specialists	Ministry of Maritime Affairs and Fisheries, Master Plan of Marine and Ocean Policy, 2004 Policy direction of Marine and Ocean Technology, Development and Investment, www.mltm.go.kr, 17th April 2009

[14] Jung B. - *Blue Economy as a new Growth Strategy in Korea* [at] Proceedings, International Symposium on Blue Economy Initiative for Green Growth, Korean Maritime Institute, Seoul, Korea, May 7, 2009, pp. 103 -121.

Also oceanographic research, especially this targeting the living and energy resources are coordinated by governments through international cooperation agreements between European Union and overseas coastal states endowed with natural resources of high interest in European markets.

The marine policy of European Union was formulated in 2006 and submitted for international discussion among member states. It is an ambitious program with multi-disciplinary approach where a lot of attention was given to international relations[15].

Foreign aid supporting maritime economies, fisheries, coastal economic activities and oceanographic research are harmonized by EU missions overseas and supported by international cooperation agreements allowing European fleets to exploit marine living resources, employ local crews and support their vessels in the local ports.

5.3 Access to overseas resources and national security interests

Access to the strategic resources, especially energy, including off-shore resources, might affect the national security of any country. It depends not only of the external but also internal forces although their interplay is frequently blurred under influence of globalization and economic integration between individual states. These factors are not limited by geographic barriers or political and economic systems. In such system of interrelationships, any possibilities and also risks have a global character [16].

For example, for Poland, and for many other nations, one of the most important foreign economic policy goals is creation of favorable conditions of access, to the energy resources localized in the economic zones of other countries or regions. The growing demand for oil and gas in Europe, more and more frequently coming from deposits located in the continental shelves, is used by the energy exporters as a tool to develop political pressures on the consumption markets.

These pressures with increasing frequency are replacing the military force in disposition of states with available energy resources. Tensions produced by temporary limitations of gas supplies to some importing countries indicate to the uncertainty of the energy market and strong influence of the politics on national economies. It is, therefore, necessary to promote overseas investment and partnerships to secure access to the natural resources of the ocean for our country. Besides undeniable benefits, an integration of the world economy brings the risk of economic crisis and destabilization of the financial markets. Climate changes have social and political consequences while competition to gain access to the ocean resources is increasingly the cause of international conflicts[17].

Intensification of the debate on protection of the natural environment and the future of energy resources of the Arctic Ocean are clear examples of growing tensions between coastal states adjacent to this Ocean and non-coastal countries interested in energy extracted from the ocean's sub-soil and coastal regions of the Arctic [18].

5.4 Taking advantage of maritime heritage of the EU's new-member states

Despite long tradition, existing human resources, available infrastructures, and sizable maritime experience gained during last decades, several coastal economies of the new member states do not fully participate in the economic integration of the World maritime economy. Due to the growing competition, continuation of this trend might negatively affect positive impacts of globalization including sub-optimal use of the cadre of specialists and marine managers educated by national universities during last century.

Some of them developed distant-water fisheries, shipbuilding and marine transportation. They occupied important position and have aspirations to continue as active maritime nations in the world.

[15] *Toward the future European marine Policy: European Visio of oceans and seas*. Green book. 275 final version presented by the Commission. Commission of the European Communities, Brussels, July 6, 2006.

[16] Kaczynski V.M. - *US Ocean Policy Toward Russia.* Jackson School of International Studies - REECAS News Letter, University of Washington, Seattle, Spring 2002.

[17] *The Defense Strategy of the Republic of Poland: Sector Strategy to the National Security of Poland.* Ministry of Defense, Warsaw 2009.

[18] Kaczynski V., Brosnan I., Leschine T. - *The Future of the Arctic: Major issues and national policies of the five coastal Arctic nations regarding the development and protection of the Arctic*. Study for the Korean Maritime Institute, School of Marine Affairs, University of Washington, Seattle, November 2009.

Figure 4. Construction of the navy ship – corvette “Gawron” type in Gdynia Shipyard
(source: Naval Shipyard Gdynia, Photo Gallery, 2009, www.navship.pl/en/photo-gallery-naval-shipyard-gdynia/category/25-korweta.html)

The production potential of their shipyards is still significant and is higher than capabilities of many other countries. These shipyards could move to produce oil and gas platforms, auxiliary ships for oil and gas extraction industry and build underwater constructions used to extract energy from the bottom of the sea. Other nations such as US, Norway, Korea, China, Japan and the West European countries have invested and undertaken various initiatives to increase their capabilities to exploit ocean and coastal resources. The principles of sustainable marine economy that could be adopted by many European countries might have powerful impact on their overall economy and affect satisfaction of their needs and oceanic aspirations.

5.5 A leadership role for European Union in shaping marine cooperation with developing countries

Current research effort, international debates, renewed attention to the Blue Economy and Green Growth create an opportunity for EU to take a leadership position in the emerging initiatives leading to the sustainable use of ocean resources. These activities are bringing global attention to the challenges and values of this sustainable approach to exploiting the richness of the ocean. For EU, active support for the Blue Economy is consistent with its commitment to green policies.

The new EU initiatives provide an opportunity for partnership between European companies and private sector partners or governmental organizations in developing countries. Working together, they can promote coastal economic development using several key industries where European firms currently excel:

- biotechnology and genetics - these are a base for aquaculture and the development of drugs and other substances,
- shipbuilding - the EU’s shipbuilders can diversify into sectors of the Blue Economy, such as offshore platforms and submerged power generation structures,
- off-shore oil and gas resource exploration and exploitation in cooperation with the developing coastal states - this includes oil and gas transportation services for the off-shore oil and gas rigs,
- marine fisheries - the EU’s experience and achievements in marine living resource use and management will be an important asset that could be used when negotiating fisheries cooperation agreements with the coastal states.

Furthermore, cooperation in ocean industries will contribute to the achievement of goals to which European Union is now committed: application of scientific disciplines in international ocean activities; strengthening cooperation between European industry and governmental institutions; and training engineers, scientists, and business personnel to work in expanding economies of the developing coastal countries.

Together, these initiatives could become an epicenter of application of the European Blue Economy overseas, attracting marine industry, governmental agencies, start-up companies, venture capitalists, students, engineers, and scientists, just as California's "Silicon Valley" attracted computer-age enterprise and talent thirty years earlier.

6 Conclusions and recommendations

During last decades the European Union has undertaken many initiatives in order to modernize and expand maritime capabilities of its member-states. Education of young cadres is considered as one of the most important success stories of an effort to occupy important position in quickly globalizing marine economy.

This integration and new technologies as well as a growing demand for the natural resources, including energy from the sea, open new possibilities and challenges. Successful attainment of international marine policy objectives is dependent on a close cooperation between the EU countries and adherence to the principles sustainable marine economy.

We are witnessing the rapid creation of the ocean industry in the world and our knowledge of the ecosystems and environmental change is constantly growing. This new strategy relies on an application of innovations in exploitation of natural resources from marine environment including production of energy and mineral resources, as well as in securing stable sources of protein.

Introduction of sustainable and environmentally friendly economy is facilitated by the experience of many European countries gained in the land-related activities (green growth). Such countries like Korea, China, Japan, United States and Norway develop their maritime potential in order to secure supplies of energy resources, marine minerals, fish protein increasing efficiency of their shipping and scientific research capabilities.

An access to these resources could have a powerful impact on the national security. The new coastal states of the European Union have good chances to join leading maritime nations of the World using their specialists, long-term experience and own maritime potential. There is a need to increase European Union's support for new members of the Union in their effort to open an access to various marine opportunities overseas with special focus on the strategically important resources in the oceans and coastal zones of the developing states. They should also pay more attention to the resource potential and shipping opportunities of the Arctic region. These countries are facing an important decision today to direct its maritime interests to the deep waters of the global ocean in order to take advantage of vast possibilities it offers to those who appreciate its riches and its role in integration of national economies with expanding international markets.

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REFERENCE MODEL OF PROJECT PROTOTYPING PROBLEM

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Abstract: The paper presents the idea of reference model of project prototyping problem for the projects that are at risk of failure. The hierarchical structure of declarative model connects two fields: functionalities of a typical service enterprise and management system of project execution in the enterprise. The functionalities as separate Constraints Satisfaction Problems (CSP) are described. CSP contains the sets of decision variables, their domains and constraints, which link these variables. The separated problems described as CSP, then in single main CSP are integrated. On the other hand, these problems can decompose into the subproblems concerning the functionalities of different fields. The open structure of model enables to solve the decision problems with different level of specificity. The decision problem can regard a query about the results of proposed decisions as well as the decisions guaranteeing the expected results. A declarative kind of proposed reference model in a natural way allows to implement its in constraint programming languages. The possibility of this approach illustrates an example.

Key words*:* project management, reference model, constraints satisfaction problem, constraint programming, alternative projects, knowledge base, decision support system, allocation planning.

1 Introduction

In the activity of present organizations more and more importance takes projects. A project is a sequence of unique, complex, and connected activities having one goal and that must be completed by a specific time, within budget, and according to specification [11]. Hence, there is an increase of the demand for new knowledge that enables solution of the problems during the complex project execution. In this case, the knowledge concerning project management has the particular significance. Especially, the identification of project success or failure is desirable, what is usually connected with specific methods and techniques.

Many cases of projects indicate that fewer than half of projects met cost and schedule targets [6, 13, 17, 20 and 23]. The findings of various other authors indicate that projects which overrun are more common than projects which complete within original time scales, overruns likely to be between 40% and 200% [16]; for instance, only one third of World Bank projects met their aims, with typical delays of 50%. Another survey showing only 17% of projects meeting all three aspects of the project triangle (cost, time, and scope), with typical cost overruns as high as 189% [7]. In the case of software projects, the surveys on estimation performance report that 60-80 percent of all software projects encounter effort overruns [8, 12 and 21].

Project success or failure depends on many critical factors, such as the kind of project, accessibility of resources, project management, and environment [2, 16]. The reasons for project failure can be generally considered in accessibility of resources (e.g. human, financial, raw materials) and changeability of the external environment. Moreover, unstable requirements, lack of well-defined scope, quality of management, and skill of the employees can cause project failure. Another factor is that an enterprise, which carries out a few projects, can change the priority of a project.

The effective project development requires planning that supports, among other things, the estimation of project progress, resources, time, etc., which are fundamental to guide the project activities. To reduce project overruns, there are two ways to approach the problem. The first way is to increase the accuracy of the estimates through a better estimation process and the second, to increase the project control.

It is unrealistic to expect very accurate estimates of project effort because of the inherent uncertainty in development projects, and the complex and dynamic interaction of factors that influence on its development.

However, even small improvements will be valuable, especially by large-scale projects. More accurate forecasting supports the project managers in planning and monitoring the project, for instance, in the project price set, required cost, resource allocation or schedule arrangement.

If the project does not develop according to the plan, there is a need for project rescuing. The subject of project rescuing in preventing phase usually focuses on the issues of starting with well-defined requirements, more accurate planning and controlling of project execution or frequent meetings between project team members [10]. In case of essential variance between the original project schedule of due tasks and the actual project schedule of done tasks, there are a few simple rules, e.g. add resources to reduce the resource bottlenecks or change the requirements and the commitment to customers [15, 24]. However, in the research works is a lack of the approach that will generate a set of alternative variants of project completion and support the decision-maker. The alternative variant is considered as a modification of the original project that can regard time, cost or scope of a project.

Rapidly changing expectations related to supporting strategic decisions, as well as aiming to reduce cost and investment risk, result in the need to make a task-oriented decision support system. Most of the publications have separately considered the fields of enterprise and project management. This results in a separate knowledge base respectively for an enterprise and project management. Consequently, it implies the difficulty of implementation of these fields within a single tool that is used for decision support. Hence, there is a need to build a single model that combines the fields of enterprise and project management, and that provides a base for making a task-oriented decision support system.

The paper is organized as follows. A reference model concerning an enterprise and project management, which is described in a standard form of the so-called constraint satisfaction problem, is presented in section 2. A project prototyping problem is formulated in section 3. A method for obtaining alternative variants of projects is shown in section 4. An illustrative example of the approach, which presents a possibility of decision problem specification in the straight and in the reverse way, is presented in section 5. Finally conclusions and future research are presented in section 6.

2 Reference model

An enterprise as a complex system [3] may be described by multiple criteria regarding its structure and environment, as well as allowing for a variety of enterprise classifications. The exemplary fields of a enterprise activity, its environment and classification are shown in Fig. 1.

Note that each area can be described by a set of criteria, measures hereinafter referred to as decision variables. An example might regard a determination of the enterprise's size by number of employees, annual turnover or production volume. Moreover, these areas can be interrelated, e.g. volume of materials purchased in a given time depends on information concerning the planned sale, manufacturing (among others things available capacity) or stocks of these materials in storage.

In the same way, it is also possible to consider project management issues. According to the Project Management Institute [14], project management consists of nine knowledge areas (see Fig. 2).

The project implementation follows according to kind of the enterprise and its resources. For this reason, the fields of enterprise activity influence on the fields of project management. For instance, the type of enterprise activity determines the feasibility of a project. Also size or type of organisation determines a project execution, because small private business by financial and personal constraint, cannot assure the available resources for large-scale project, for example, airport building.

The proposed approach combines the fields of an enterprise and project management in form of single platform – the reference model. This way seems to be natural in case of an enterprise that executes projects and solves standard decision-making problems. In this case, a knowledge base is created that in addition to the inference strategies allows to implement a decision support system more efficient.

The fields of enterprise activity and project management (see Fig. 1 and 2) regard a general case, that allows describing any type of project in any enterprise. To illustrate an idea of a connection these fields into one reference model, the general case is thereinafter limited to the medium service enterprises, which implement software project.

Enterprise

Environment
- political
- economical
- technological
- social
- nature

Functionality fields
- procurement
- manufacturing
- sales
- warehouse management
- marketing
- finance
- human resources
- accounting

Size
- micro
- small
- medium
- large

Type of organization
- private
- cooperative
- local government
- public

Localizations
- one place
- multi place
- network

Type of activity
- production
- trading
- services

Organizational structure
- bureaucratic
- functional
- divisional
- matrix
- mixed

Type of legislation
- company limited by guarantee
- company limited by shares
- limited-liability company

Internationalization
- national
- international
- multinational
- global

Figure 1. Fields of enterprise activity
(source: self study)

Project management

Integration management
- developing the project plan
- executing the project and producing deliverables
- monitoring the progress
- integrating change controls
- closing the project

Scope management
- scope defining
- creating work breakdown structures
- verifying and controlling the scope

Time management
- defining activity
- estimating the duration of activities
- estimating resource activities
- developing and controlling schedules

Cost management
- estimating costs
- budgeting costs
- controlling costs in a project

Human resource management
- resource planning
- resource acquiring
- developing and managing the project team

Quality management
- planning quality
- assuring quality
- controlling quality

Communications management
- communications planning
- information distribution
- reporting performance
- stakeholder management

Risk management
- risk identification
- risk analysis
- risk response planning
- risk monitoring and control

Procurement management
- procurement planning
- solicitation planning
- source selection
- contract administration

Figure 2. Description of project management
(source: self study with the use of [14])

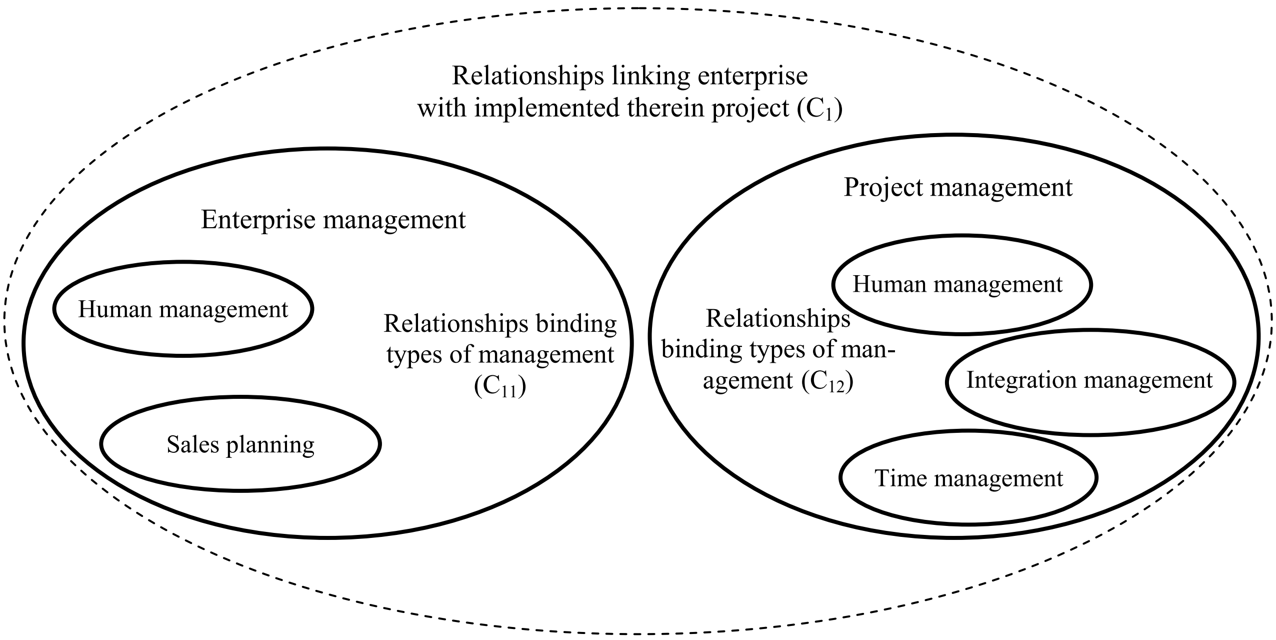


Figure 3. Hierarchical structure of reference model
(source: self study)

Both in enterprise and in project management, some functionalities occur. They may regard the same field, e.g. human resource management (both for the administrative divisions of enterprise, and for a project) as well as they may make a separate field, e.g. sales planning or project integration management.

An exemplary set of functionalities in enterprise and project management is presented in Fig. 3. The management fields are combined by constraints that are distinguished in Fig. 3 as C_1. For instance, the number of employees of enterprise should be greater than demand connected with project implementation. Another example of constraint, that links both considered fields, may concern greater number of financial means in the enterprise than the expenditure of a project. The functionalities concerning enterprise and project management include common elements strictly regarding the management, what by C_{11}, C_{12} is distinguished in Fig. 3. For instance, human resource management encompasses planning, organizing, staffing, leading, motivation, and controlling. Application of these elements takes place in terms of enterprise activity fields (see Fig. 1). In this case, human resource management depends on, among other things, environment (e.g. circumstances on domestic and international market) or the kind of enterprise (different staffing policy in private and public organization). Implementation of other functionality concerning sales planning bases on, for example, the kind of enterprise activity; in the case of production enterprise, the sales planning should take into account e.g. a workplace schedule.

In the same way, the relationships linking different functionalities in the project management may be described, what by C_{12} is distinguished in Fig. 3. In this case, the functionalities depend on management elements such as planning or controlling as well as these are determined by the kind of a project, for example, integration management or time management are different for software project and building project.

The enterprise model can be described by its resources. The project model is created from the requirements of the client. In these models, some parameters are determined, among which a set of decision variables and constraints may be distinguished. The constraints connect the variables that describe the capacity of the enterprise as well as the variables that concern the conditions of project implementation. For instance, the number of the enterprise's employees limits the duration of the project. This means that fulfilment of specified constraints enables project completion according to client requirements.

A way of model specification regards in general a declaration of the sets of decision variables, their domains, and constraints that imposed on subsets of variables. In this context, it seems natural to classify some decision problems as Constraints Satisfaction Problem (CSP).

A considered approach of specification, determined by constraints of reference model of decision problem, enables a simplified description of actuality, i.e. a description encompasses the assumptions of object, implementing therein tasks, and a set of routine queries (the instances of decision problems) that in framework of CSP are formulated.

It is assumed that the reference model for project prototyping problem has the structure of constraints satisfaction problem, and it may be described as follows:

$$CSP = ((V, D), C) \quad (1)$$

where:

$V = \{v_1, v_2, ..., v_n\}$ – finite set of n variables,

$D = \{D_1, D_2, ..., D_n\}$ – finite and discrete domains D of variables, where $D_i = \{d_{i1}, d_{i2}, ..., d_{ir}\}$,

$C = \{c_1, c_2, ..., c_m\}$ – finite set of m constraints limiting and linking decision variables.

Each constraint treated as a predicate can be seen as an n-ary relation defined by a Cartesian product $D_1 \times D_2 \times ... \times D_n$. The solution to the CSP is a vector $(d_{1i}, d_{2k}, ..., d_{nj})$ such that the entry assignments satisfy all the constraints C. So, the task is to find the values of variables satisfying all the constraints, i.e., a feasible valuation. Generally, the constraints can be expressed by arbitrary analytical and/or logical formulas as well as link variables with different non-numerical events.

Thus, a constraint can be treated as a logical relation among several variables, each one taking a value in a given (usually discrete) domain. To solve such a problem stated by the set of requirements (constraints) that specify a problem at hand, the concept of constraint programming (CP) is employed.

CP is an emergent software technology for declarative description CSP and can be considered as a pertinent framework for development of decision support system software aims. The main idea behind the CP concept is based on subsequent phases of constraint propagation and variable distribution [18].

The assumed model enables descriptive approach to the problem statement, encompasses constraint satisfaction problem structure and then allows implementation of the problem considered in the constraint programming environment. The idea behind the proposed approach assumes the system considered can be represented in terms of a knowledge base (KB).

KB comprises of facts and rules determining the system's properties and relations linking them respectively. Taking into account the concept of constraints propagation and variables distribution following from the constraint programming languages it is easy to note that any KB can be represented in a standard form of the CSP [22].

KB can be specified in terms of a system [5]. At the input of the system are the variables regarding the fundamental attributes of the object that are known and given by the user. In the considered KB for the enterprise-project model, there are, for example, variables concerning the amount of an enterprise's resources or the project structure. The output of the system is described by the attributes of the object that are unknown or are only partially known. In the considered case, there can be included variables regarding e.g. the cost or time of activity or usage of resources.

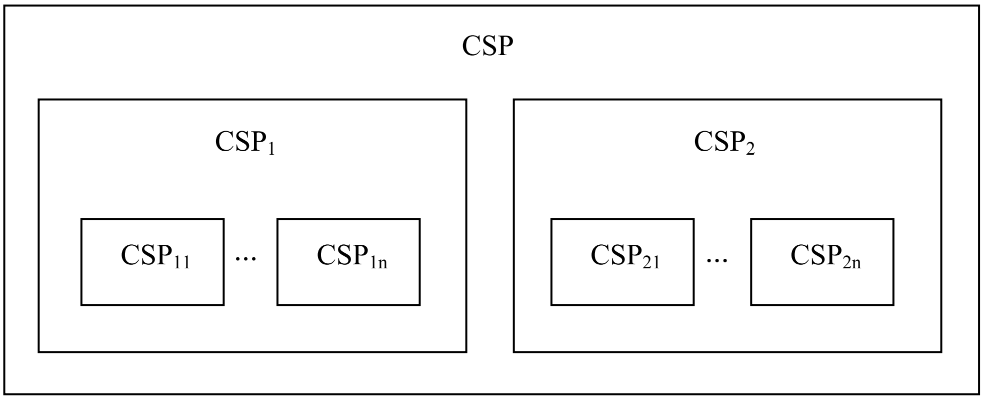
Classification of the decision variables in KB as input-output variables is arbitrarily made and permits to formulate two classes of standard queries, in a straight and in a reverse way, as follows [1, 4]:

- a straight way (i.e. corresponding to the question: what results from premises?), e.g. Does a given resources allocation guarantee the schedule does not exceed the given deadline?
- a reverse way (i.e. corresponding to the question: what implies conclusion?), e.g. What times of activity duration and number of resources guarantee the given schedule does not exceed the deadline?

The above-mentioned categories encompass the different reasoning perspectives, i.e. forward and backward reasoning. The corresponding queries can be stated in the same model that can be treated as composition of variables and constraints, i.e. assumed sets of variables and constraints limiting their values. In this context, the problem statement of project prototyping, which is specified in terms of CSP, are presented in next section.

3 Problem statement of project prototyping

Presented in Fig. 3, the hierarchical structure of reference model implies a similar structure concerning constraints satisfaction problem. The idea of this approach is presented in Fig. 4.



Fgure 4. Struture of Constraints Satisfaction Problem
(source: self study)

The reference model in the form of single CSP can be described. The CSP consists of enterprise management (CSP_1) and project management (CSP_2). In turn, CSP_1 and CSP_2 contain other elements describing the functionalities in the considered areas (CSP_{11}, ..., CSP_{1n} and CSP_{21}, ..., CSP_{2n}).

Assuming two-level structure of reference model of project prototyping problem (RMPPP), it may be described as follows (see Fig. 3 - 4 and formula 1):

$$RMPPP = ((CSP_1, CSP_2), C) \tag{2}$$

CSP_1 regards the field of enterprise activity, CSP_2 – the field of project management, and C describes the constraints linking these fields in single Constraints Satisfaction Problem. This is defined following:

$$CSP_1 = ((\{R_1, R_2\}, \{D_{R1}, D_{R2}\}), C_{CSP1}) \tag{3}$$

where:

$R_1 = \{r1_{1,1}, ..., r1_{m,h}, ..., r1_{M,H}\}$ – a number of m-th financial resource (e.g. cash, deposits, short-term payments) in h-th time unit (h = 0, 1, ..., H); given a set of resources $R = (R_1, ..., R_k, ..., R_z)$,

$R_2 = \{r2_{1,1}, ..., r2_{n,h}, ..., r2_{N,H}\}$ – a number of working hours for n-th group of employees (e.g. programmers) in h-th time unit,

D_{R1} – a set of admissible financial means R_1, $r1_{m,h} \in D_{R1}$,

D_{R2} – a set of admissible working hours R_2, $r2_{n,h} \in D_{R2}$; note that for the known values of decision variables the domain is a set with single element.

C_{CSP1} – a set of constraints:

- $C_{CSP1,1}$ – a number of available financial means in enterprise equals a amount of cash ($r1_{1,h}$), deposit accounts ($r1_{2,h}$), short-term payments ($r1_{3,h}$) and bank loans ($r1_{4,h}$) in h-th time unit:

$$r1_{1,h} + r1_{2,h} + r1_{3,h} + r1_{4,h} = r1_h \tag{4}$$

- $C_{CSP1,2}$ – a number of working hours in enterprise is not greater than the sum of product of n-th employees group (analysts – $r2_{1,h}$, consultants – $r2_{2,h}$, programmers – $r2_{3,h}$) and a number of hours in a working day; it is assumed, a working day equals 8 hours plus available 2 hours of overtime during a project implementation:

$$10 * (r2_{1,h} + r2_{2,h} + r2_{3,h}) \leq r2_h \tag{5}$$

In case of project management area (CSP_2), a functionality concerning scheduling has been chosen. It is assumed, each project P_i consists of J activities: $P_i = \{A_{i,1}, ..., A_{i,j}, ..., A_{i,J}\}$. Moreover, it is assumed:

- each activity can be implemented by applying at least one of enterprise resources,
- indivisibility of activity,
- activity can start its execution only if required number of resources are available at the moments given by $Tp_{i,j}$ and after completed previous activity,
- each resource can be used by an activity only once,
- a number of resource used by an activity cannot be changed or allotted to other activity.

The resource can be allotted or released only after completion the activity that requires this resource. It is assumed, a number of available resources $r_{k,h}$ in h-th time unit is known. The planning horizon H contains a set of variables concerning the starting moments of the successive time units.

The field of project management can be described as follows:

$$CSP_2 = ((\{P_i, A_{i,l}, s_{i,j}, t_{i,j}, Tp_{i,j}, Tz_{i,j}, Dp_{i,j}\}, \{D_{Pi}, D_{Ai}, D_{si}, D_{ti}, D_{Tpi}, D_{Tzi}, D_{Dpi}\}), C_{CSP2}) \quad (6)$$

where:

P_i – i-th project,

$A_{i,j}$ – j-th activity of i-th project that is specified following: $A_{i,j} = (s_{i,j}, t_{i,j}, Tp_{i,j}, Tz_{i,j}, Dp_{i,j})$,

$s_{i,j}$ – the starting time of the activity $A_{i,j}$, i.e., the time counted from the beginning of the time horizon H,

$t_{i,j}$ – the duration of the activity $A_{i,j}$,

$Tp_{i,j} = (tp_{i,j,1}, tp_{i,j,2}, ..., tp_{i,j,z})$ – the sequence of allocation moments by the activity $A_{i,j}$ required the resources: $tp_{i,j,k}$ – the time counted since the moment $s_{i,j}$ of a number $dp_{i,j,k}$ of the k-th resource allocation to the activity $A_{i,j}$; that means a resource is allotted to an activity during its execution period: $0 \leq tp_{i,j,k} < t_{i,j}$; $k = 1, 2, ..., z$,

$Tz_{i,j} = (tz_{i,j,1}, tz_{i,j,2}, ..., tz_{i,j,z})$ – the sequence of moments, when the activity $A_{i,j}$ releases the resources: $tz_{i,j,k}$ – the time counted since the moment $s_{i,j}$ of a number $dp_{i,j,k}$ of the k-th resource release by the activity $A_{i,j}$; that means a resource is released by activity during its execution period: $0 < tz_{i,j,k} \leq t_{i,j}$; $tp_{i,j,k} < tz_{i,j,k}$; $k = 1, 2, ..., z$,

$Dp_{i,j} = (dp_{i,j,1}, dp_{i,j,2}, ..., dp_{i,j,z})$ – the sequence of number of the k-th resource is allocated to the activity $A_{i,j}$: $dp_{i,j,k}$ – a number of the k-th resource allocation to the activity $A_{i,j}$; that assumes: $0 \leq dp_{i,j,k} < R_k$; $k = 1, 2, ..., z$;

D_{Pi} – a set of admissible number of projects in the enterprise,

D_{Ai} – a set of admissible number of activities in i-th project,

D_{si} – a set of admissible starting times of activity $A_{i,j}$ in i-th project,

D_{ti} – a set of admissible duration of activity $A_{i,j}$ in i-th project,

D_{Tpi} – a set of admissible allocation moments to activity $A_{i,j}$ for k-th resource in amount of $dp_{i,j,k}$, in i-th project,

D_{Tzi} – a set of admissible release moments by activity $A_{i,j}$ for k-th resource in amount of $dp_{i,j,k}$, in i-th project,

D_{Dpi} – a set of admissible number of required resources by the activity $A_{i,j}$ in i-th project,

C_{CSP2} – a set of constraints:

- $C_{CSP2,1}$ – constraint concerning horizon of project completion $H = \{0, 1, ..., h\}$:

$$\forall s_{i,j} \ \forall t_{i,j} \ (s_{i,j} + t_{i,j} \leq H) \quad (7)$$

- $C_{CSP2,2}$ – order constraints:
  - the k-th activity follows the i-th one:

$$s_{i,j} + t_{i,j} \leq s_{i,k} \quad (8)$$

  - the k-th activity follows other activities:

$$\begin{aligned} & s_{i,j} + t_{i,j} \leq s_{i,k} \\ & s_{i,j+1} + t_{i,j+1} \leq s_{i,k} \\ & \dots \\ & s_{i,j+n} + t_{i,j+n} \leq s_{i,k} \end{aligned} \quad (9)$$

  - the k-th activity is followed by other activities:

$$\begin{aligned} & s_{i,k} + t_{i,k} \leq s_{i,j} \\ & s_{i,k} + t_{i,k} \leq s_{i,j+1} \\ & \dots \\ & s_{i,k} + t_{i,k} \leq s_{i,j+n} \end{aligned} \quad (10)$$

In the reference model of project prototyping, the constraints C are the elements linking CSP_1 and CSP_2 (see formula 2).

These constraints contain:

C_1 – the financial means for i-th project $r1_{h,i}$ cannot be greater than total value of admissible in the enterprise financial means $r1_h$ in h-th time unit:

$$r1_{h,i} \leq r1_h \quad (11)$$

C_2 – an admissible number of working hours $r2_{h,i}$ for i-th project and n-th group of employees cannot be greater than total number of admissible in the enterprise working hours $r2_h$ in h-th time unit:

$$r2_{n,h,i} \leq r2_h \quad (12)$$

It is assumed, for each i-th project there are *l* alternative variants its implementation $P_{l,i}$. Alternative variant is understood as project, which parameters concerning time, cost or scope are different from the parameters of original project.

The routine queries can be formulated in the straight and reverse way for considered RMPPP. In case of the straightway, the considered problem regards the answer to the following question: is there a schedule meeting constraints for given values of variables, and if so, what are its parameters?

$$C = \{(11), (12)\}$$

$$CSP_1 = ((\{R_1, R_2\}, \{D_{R1}, D_{R2}\}), \{(4), (5)\})$$

$$CSP_2 = ((\{P_i, A_{i,l}, s_{i,j}, t_{i,j}, Tp_{i,j}, Tz_{i,j}, Dp_{i,j}\}, \{D_{Pi}, D_{Ai}, D_{si}, D_{ti}, D_{Tpi}, D_{Tzi}, D_{Dpi}\}), \{(7), (8), (9), (10)\})$$

Figure 5. Reference model for declarative statement of project prototyping project
(source: self study)

This question can be expanded to the next, for instance, does a given schedule not exceed the given deadline H, financial resources r1 and working-hours r2 in time unit h? It allows a class of multicriteria problems to be taken into consideration.

If for the straight way there is no schedule, then is assumed that original project execution is at risk of failure. Thus, a question concerning the reverse way can be formulated: what values of variables guarantee the completion of the project by given constraints? The choice of variables, which values are changed according to assumed constraints, depends on the considered problem, and in an arbitrary way is determined.

The method concerning the determination of admissible solutions for the above-described problem in terms of cost estimating is presented in next section.

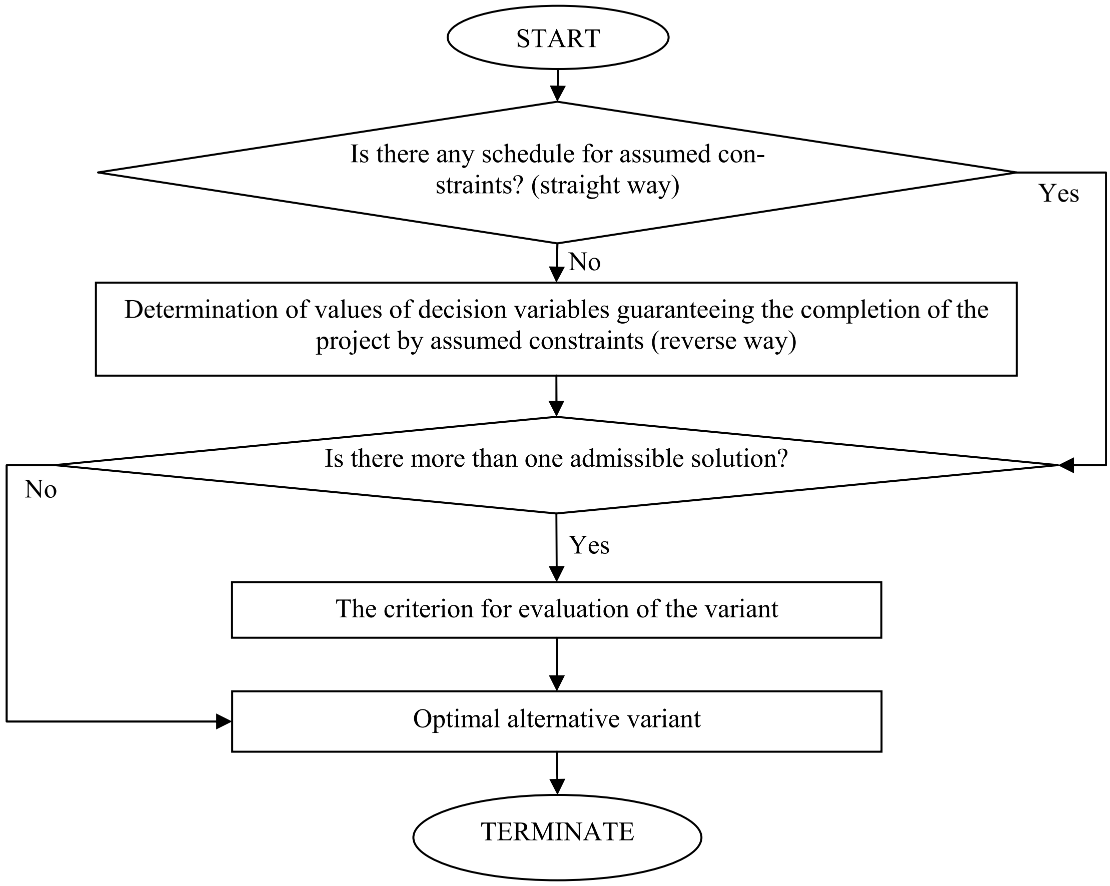


Figure 6. Project prototyping procedure for projects at risk of failure
(source: self study)

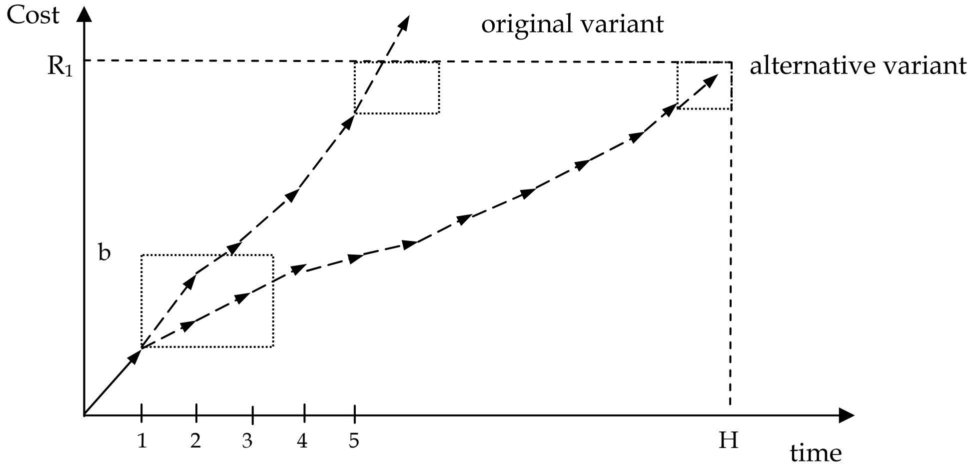


Figure 7. Example of project prototyping
(source: self study)

4 Method of obtaining feasible solutions of project

The planning issue and then the successive monitoring of the project, is one of the most important elements of project management that determines its success or failure [9].

So, there is a need to develop method that will enable an early detection of discrepancies in a project execution. Moreover, the method should determine the alternative variants that meet the goal of the project and avoid the estimated discrepancies.

The stages of proposed method is presented in Fig. 6. If for the assumed constraints there is no schedule (e.g. estimated cost of project is greater than available financial means), then with using of reverse way, the values of decision variables, which guarantee a project execution, are determined.

The functionality concerning cost estimation is chosen as an example illustrating the idea of the proposed, implemented as RMPPP, approach. Exemplary alternative variant of project is presented in Fig. 7. It is determined if cost estimation indicates a lack of possibility for original project implementation by assumed constraints. The cost estimation is an additional constraint, into RMPPP is added and in form of CSP_{2n} is described.

It is assumed, an assessment of activity completion, as well as a redetermination of an admissible solutions set follows in time unit h. Trajectory of project execution, distinguished by solid line, indicates cost of completed activities as well as activities in progress in first time unit. Approximating the cost function can be set its values in next time units. This is presented in Fig. 7 by dashed line. An interval belongs to a set of admissible solutions that in form of rectangle is distinguished in Fig. 7. The size of set is connected with the domains of variables and the assumed constraints. The a interval depends on the order constraints between activities and project time horizon, so in result on slack time. The b interval depends on constraint concerning the financial means r1 in time unit h.

If cost estimate is greater than assumed financial constraint (original variant), then alternative variant is sought that fulfils the assumed time (H) and financial (R_1) constraints. If a set of admissible solutions is multi-elements, then the variants according to assumed criterion are assessed. The criterion may regard, for instance, minimisation of time or cost of the project execution. An example of the assessment is presented in Fig. 8.

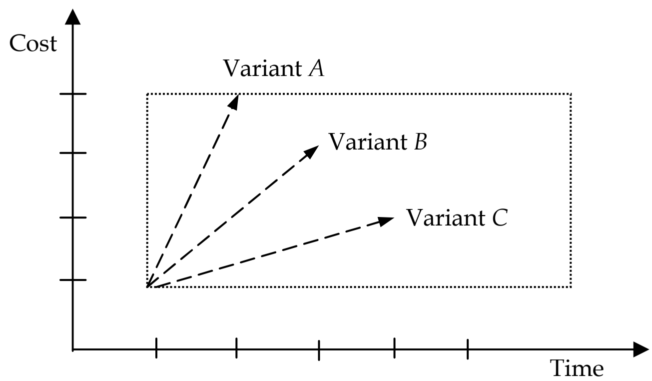


Figure 8. Example of variants evaluation
(source: self study)

The choice of a variant of the three depends on an assumed by decision-maker criterion. If criterion concerns the minimisation of time, then variant A is most profitable. In case of cost minimisation, variant C is most advantageous. For combined criterion, i.e. minimisation of time and cost with equal weights – all variants are equally advantageous.

The advantages of proposed approach contain an obtaining of admissible solutions set in time unit h. In case of predictable difficulties with project execution, the approach enables a choice of alternative variant and in general the preventing to exceed the assumed constraints. This also refers to inability of some activities execution, and searching a possibility of project completion in another form. An example concerning the described approach is presented in next section.

5 Illustrative examples

The example aims to illustrate a possibility of CSP specification for decision problem of project prototyping. Problem in the straight and in the reverse way is formulated.

5.1. Routine queries formulated in the straight way

Example 1

The project concerns a software implementation in sales field of trading company. The orderer has got software in sales, but it contains limited functionality and the integrity with other domains of software is not ensured. The required additional features include making offer, registration of order, assignment the trade credit to customer, analysis of customer loyalty (frequency of sales and payments), and assignment a few payment terms.

The project contains seven activities:

1) analysis of business processes, IT systems, database structure in the client company,
2) new software installing, initial configuration and testing,
3) customisation of standard software setting according to the client requirements,
4) customisation according to the untypical client requirements and building interfaces to link software concerning different fields of enterprise activity,
5) formulating a way of data migration, from previous software database to new one,
6) final configuration and testing software,
7) users training.

The activity network diagram for considered project $P = \{A_1, ..., A_7\}$ is presented in Fig. 9.

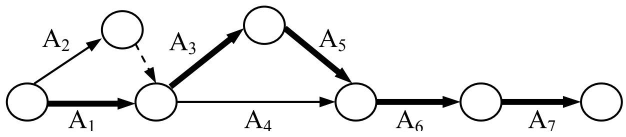


Figure 9. Activity network of the project
(source: self study)

Operation times (in working hours) for the project are determined by using past experiences as follows: T = (16, 8, 16, 30, 16, 16, 60). In Fig. 9, the bolded arrows indicate the critical path with total time equals 124 working hours.

The software company can allocate for the project three employees: one programmer and two consultants. Programmer can work by activities A_2-A_6, in turn consultants - activities A_1 and A_7. Thus, a number of resource $dp_{1,j}$ for activity j takes the form of the following sequence: Dp_1 = (2, 1, 1, 1, 1, 1, 2). It is assumed that consultants can work independently and parallel by activity A_1 and A_7. In this case, all activities are critical, and total time equals 116 working hours.

The analysis of the past completed projects, which belong to the same class as considered project, indicates the linear relationship between cost and activity duration: $dp_{2,j} = 1 + 0{,}5 \cdot t_j$. This relation consists fixed cost (e.g. cost of stay by client), and variable cost (hourly rate). Thus, a number of financial resources $dp_{2,j}$ allocated to the activity j is in the following form: Dp_2 = (9, 5, 9, 16, 9, 9, 31). Total planned cost of project equals 88 monetary units (m.u.). A whole number of the resources at the starting moment of activity is allocated, and only at the moment of its completion can be released.

The order constraints according to the activity network of the project and formulas (8), (9), and (10) are following:

C_1: $s_3 \geq s_1 + t_1$, C_2: $s_3 \geq s_2 + t_2$, C_3: $s_4 \geq s_1 + t_1$
C_4: $s_4 \geq s_2 + t_2$, C_5: $s_5 \geq s_3 + t_3$, C_6: $s_6 \geq s_4 + t_4$
C_7: $s_6 \geq s_5 + t_5$, C_8: $s_7 \geq s_6 + t_6$

Client sets the project completion at three weeks time (120 working hours – time horizon H = {0, 1, .., 120}), by budget equals 100 m.u.

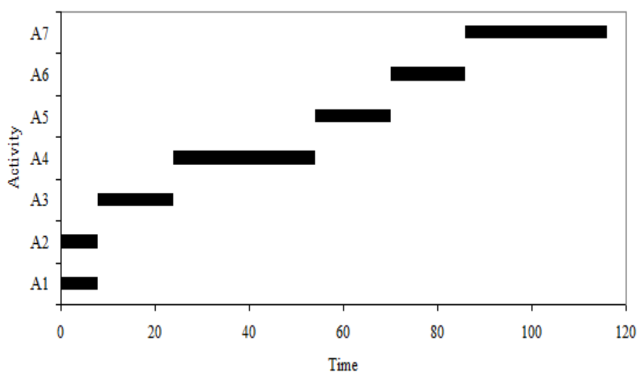


Figure 10. Gantt's chart of project
(source: self study)

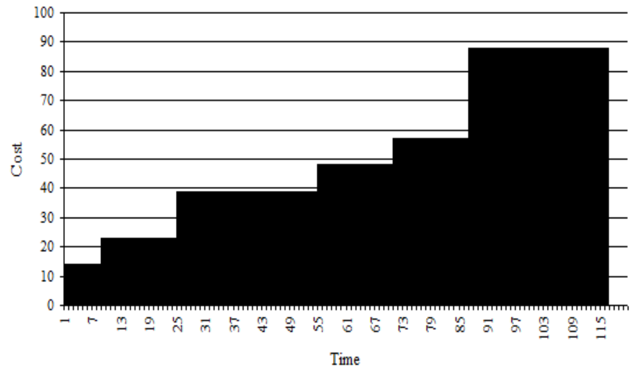


Figure 11. Gantt's-like chart of the resource usage
(source: self study)

The considered problem belongs to the class of "straight" ones where for a given parameters describing the enterprise-project system the activities schedule is sought. It reduces to the following question: is there, and if so, what form does a schedule have that completion time does not exceed the deadline H, and that fulfils the resource constraints? Note that the answer to above-mentioned question is connected with determination of the starting time of the activity s_j, where $0 \leq s_j < 120$; $j = 1, 2, ..., 7$.

The CSP-based reference model has been implemented in Oz Mozart [19]. Obtaining of the solutions took less than a second (the AMD Turion(tm) II Ultra Dual-Core M600 2,40GHz, RAM 1,75 GB platform has been used). The first admissible solution has the following form: S = (0, 0, 8, 24, 54, 70, 86). The project schedule fulfilled all constraints imposed by an enterprise capability and project requirements, is presented in Fig. 10.

The usage level of financial means in the time horizon is illustrated in Fig. 11.

Example 2

After completion of the A_1 and A_2 activities, the relationship between cost and duration of activity is again determined: $dp_{2,j} = 2 + 0{,}6 \cdot t_j$.

The sequence of the financial means can be described following: Dp_2 = (9; 5; 11,6; 20; 11,6; 11,6; 38). Thus, total cost of the project equals 106,8 m.u. Other values of decision variables, their domains, as well as the constraints are the same as in Example 1.

The considered problem also belongs to the class of "straight" ones, and it can be reduced to the following question: is there, and if so, what form does a schedule have that completion time does not exceed the deadline H, and that fulfils the resource constraints?

Similarly to the previous case the solution to the problem concerns the determination of the moments activities start their execution s_j. The planned cost of the project (106,8 m.u.) exceeds the budget of the project (100 m.u.). In this case, the set of admissible solutions is empty. That means there is no schedule. Thus, there is still a possibility to reformulate the considered problem by stating it in a reverse way, i.e. the way aimed at searching for decision variables (e.g. duration of activity) guaranteeing that the completion time of the considered project will not exceed the assumed deadline H. Such case is considered in next subsection.

5.2. Routine queries formulated in the reverse way

Assumed the same activity network, time horizon, domains of decision variables, and the constraints as in previous subsection, for straight way. Taking into account the kind of the considered software project, it is assumed that planned time of last activity (users training) is changed. This activity is connected with many factors (e.g. user's perception, education, past experiences) that hinder an accurate estimation of the activity. Assumed the minimal duration of the A_7 activity equals 30 working hours.

The considered problem can be reduced to the question: what duration of the A_7 activity guarantees that completion time of the project does not exceed the deadline H, and the resources constraints?

In order to response to this question the values of the activity duration t_7 and its cost $dp_{2,7}$ are sought. The admissible solutions is as follows $t_7 = \{30, \ldots, 48\}$.

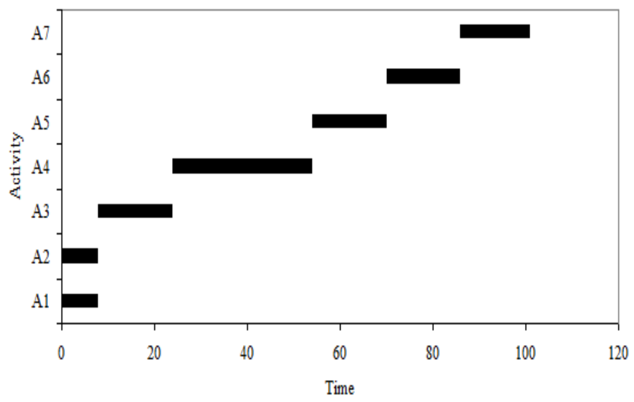


Figure 12. Gantt's chart of project according to criterion of time minimisation *(source: self study)*

For assumed constraints and discrete values, 450 sequences of the S (the starting time of the activities) are determined. The obtained variants can be evaluated according to such criteria as time, cost or a number of required employees. If criterion concerns the minimisation of time or cost, then the optimal variant is for $t_7 = 30$ working hours. Thus, total time equals 101 working hours, and cost – 88,8 m.u. Gantt's chart of project and usage of financial means for first admissible solution is presented in Fig. 12 and 13.

If criterion regards minimisation of required employees (programmer and consultants), then the solutions for $t_7 = \{30, \ldots, 34\}$ are equally advantageous, because a slack time for the project equals 4 working hours. Gantt's chart of project and usage of financial means for last admissible solution ($t_7 = 34$) is presented in Fig. 14 and 15. The assumed domains of decision variables and constraints determine the possible values of sought parameters.

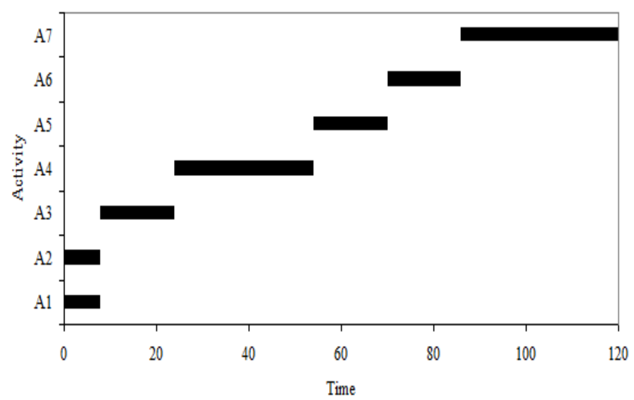


Figure 14. Gantt's chart of project according to criterion of employee's minimisation *(source: self study)*

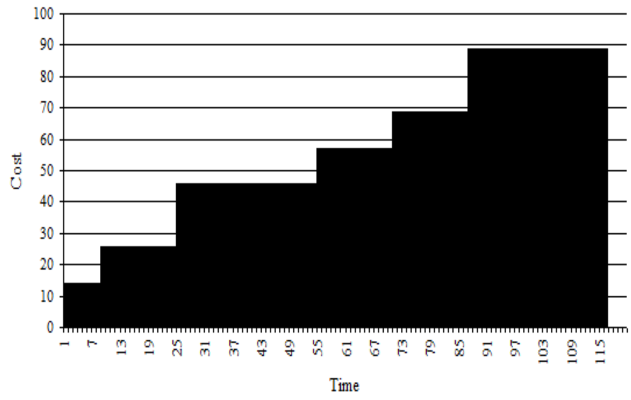


Figure 13. Gantt's-like chart of the resource usage according to criterion of time minimisation *(source: self study)*

The result is a set of feasible solutions in time unit h. Note that the number of generated solutions depends not only on the knowledge base, but also on a user-declared granularity of solutions in constraint programming languages such as, for instance, ILOG or Oz Mozart [19].

6 Conclusions

In the present, changeable business environment, the quickness of response to customer needs or pressure on innovation and the effective cost management determine the success or failure in the struggle for market position. This forces more frequent and larger-scale changes in contemporary organizations. The answer to these new challenges is the application of the principles of project management.

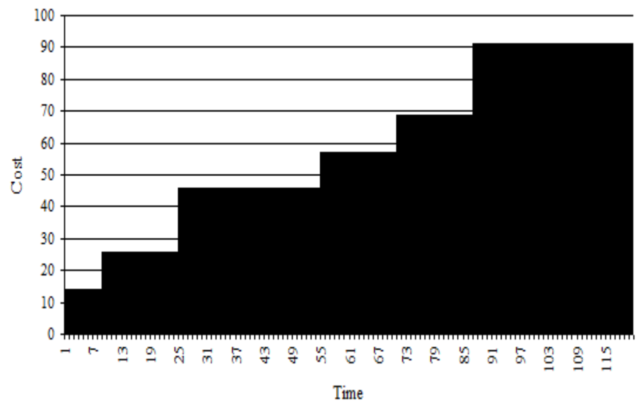


Figure 15. Gantt's-like ch art of the resource usage according to criterion of employee's minimisation *(source: self study)*

In case of projects carried out on a client order, erroneous estimation of expenditures and project deadlines may result penalties being accrued, as agreed upon in the contract or covering the costs with the company's own money. A wrong decision may worsen the liquidity of an enterprise or even lead to its bankruptcy. In this situation, it seems extremely important to support the decision maker.

The proposed approach assumes a kind of reference model encompassing open structure enabling to take into account different sorts of variables and constraints as well as to formulate straight and reverse kinds of project planning problems.

Since a constraint can be treated as a logical relation among several variables, each one taking a value in a given (usually discrete) domain, the idea of CP is to solve problems by stating the requirements (constraints) that specify a problem at hand, and then finding a solution satisfying all the constraints. Because of its declarative nature, it is particularly useful for applications where it is enough to state what has to be solved instead of how to solve it [1].

The advantages of the proposed approach include the possibility of the description of enterprise and project management in terms of single knowledge base. Moreover, in the presented approach it is possible to obtain a set of feasible solutions in the different phases of the project life cycle. This is especially attractive in the absence of the possibility of continuing the project in its original form and can support the decision maker in obtaining the alternative variants of the project.

Further research focuses on the presentation of the model reference for the project prototyping problem, when some activity cannot be completed. It should also include a comparison of the proposed approach to another approach concerning considered field. Moreover, the further research can be aimed at carrying out verification of the knowledge base of described object.

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FUNCTIONAL ENHANCEMENTS TO PROJECT MANAGEMENT INFORMATION SYSTEMS

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Abstract: Presented research work relates to information systems of projects management support. The aim of the work is to propose solutions, that will help achieve improved efficiency of information systems class PMIS implementations (Project Management Information System) especially given the scope of functionalities and implementation process realization. Presented in this article research results were obtained in the analysis of projects implemented in enterprises of the sector: construction and building, service with particular emphasis on the IT industry, and investment. Summary of the article includes both the results of the research analysis and proposed directions for their further development.

Key words: the project, the project portfolio, project management information system, project management body of knowledge, project life cycle, the cycle of implementation and monitoring of the project.

1 Introduction

Project management is a relatively new field of knowledge[1], if we accept the first works describing the methodology[2] of project management as its beginning. A project is a venture which aims to build an office building, drafting a law, producing an atomic bomb or software. The fact is that ventures, today referred to as projects[3] by methodologies, were carried out practically since the beginning of humanity. The fact that projects have been carried out for centuries without the support provided by methodologies today, often makes the field of project management undervalued in companies that base their business on projects.

Similarly, very often a company is not willing to invest funds in implementing a methodical, standardized project management approach. If business operations produce desired results at the level of whole organization, often no attention is paid to the possibility of improving the conduct of individual projects, or even to their failures. This issue is particularly relevant for Polish companies, which often in contrast to some of their Western and American counterparts, have not yet developed a culture of project management. However, this does not mean that corporations in highly-developed countries cope flawlessly with the management of unique projects.

Lack of implemented project management culture is one of the main reasons why the implementation of information systems supports project management (hereinafter referred to as the PMIS[4] class systems) are ineffective. An ineffective implementation is defined as one which although completed according to schedule and complete, did not result in a continuous and efficient use of PMIS in the organization.

One of the main reasons for the failure of implementation of these systems, which will be considered in this study, is the limitations of their functionality. Lack of functionalities tailored to the needs of individual industries, the lack of functionality tailored to the conditions of the market (Polish or other European markets), little flexibility in system configuration, or even a system poorly matched to the needs of a client, result

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[1] The origins of project management as a field of knowledge date back to the beginning of the 50s of the twentieth century. [information after Webb A. - *Earned Value in Practice*. Warsaw, PROED 2008]

[2] Methodology - a set of rules regarding a manner of execution of certain work. [*Polish Language Dictionary* PWN, http://sjp.pwn.pl/slownik/2567700/metodyka (read on 29 May 2011)].

[3] Project – a unique sequence of complex tasks, related to one another, having a common goal, intended for delivery, within a specified time, without exceeding the budget, according to set requirements [definition after Wysocki R.K., McGary R. – *Effective Project Management.* Edition III. Gliwice, Helion 2005, p. 47].

[4] PMIS – acc. to PMBOK (Project Management Body of Knowledge) standard proposed by Project Management Institute, is a Project Management Information System.

in the fact despite the efforts of the implementation team and employees, usefulness of the system may not be sufficient. Usefulness is understood as obtaining business benefits through a regular use of PMIS. The above described issues, identified in the course of professional practice, are motivators to undertake a project to improve the efficiency of PMIS implementation.

The aim of this study is to propose solutions that will help achieve improved efficiency of information systems implementation. Due to issues identified during the implementation of these systems, which are described in the introduction to the study, the focus was put on two areas where improvements are achievable:

- functional area of PMIS,
- methodical area of PMIS implementation conduct.

In order to achieve improvement in the first of these areas, the role of a project management support system will be defined, or the rationale for implementing such a system in a company. Then an analysis will be conducted of requirements relating to the functionality of these systems. This analysis aims to answer the following questions:

- What specific objectives should PMIS deliver within methodological project management?
- What specific objectives should PMIS deliver within practical needs reported by business implementation owners?
- What organizations can benefit from the use of such systems?

In the next step, methodological requirements and those derived from business owners originating from different industries, will be juxtaposed with the capabilities of selected PMIS. This set will identify the best systems in the various areas of project management to clients in various industries. In addition, knowledge about the most important requirements relating to the project management processes and definition of a set of existing functionalities, will enable to specify the functionality unique to the market. The aim of the study is therefore to summarize and compare the capabilities of existing solutions and to identify solutions that can improve IT support of project management.

This paper concerns the information systems supporting project management. Due to the fact that the concept of a project exists in many industries, it is very general. A project in each of the industries may mean a sequence of actions with a completely different specificity, which, however, due to their nature and the environment in which they are implemented, will be combined by one definition.

As a result, it is possible to distinguish techniques and methods of project management, which can be used in almost every industry, such as critical path method or the earned value method. However, there are a number of requirements of individual industries, for which specific solutions are needed to facilitate the planning, implementation and monitoring of projects.

Techniques and methods as a tool for those requirements, translated into the language of a computer system, can be identified with a functional scope that a given system provides to the user.

It was assumed that this study should not only be based on general functionalities that can be used in the majority of industries present on the market and dealing with the implementation of projects. Such a proposal is a result of experience gained in implementation of PMIS. Most clients look for a dedicated solution that is prepared to support the issues and take the challenges which are commonplace for the industry. This is due, in large part, to strong competition on the market, which provokes a practice of creating optimistic schedules and squeezing costs in order to place attractive offers in order to win tenders. It is this dynamic environment of project implementation which results in the fact that companies often do not have time for long-term, multi-phased implementations and, as a result, functionalities are adapted to the needs of a particular industry.

Adjustment works are inevitable, but the client's goal is to reduce them to a minimum. In conclusion, we need tailor-made solutions, and adjustment works, ideally, should be limited only to the specificity of an organization, not the industry.

Results of this approach are already evident at the stage of PMIS license sales. This process is often accompanied by a preliminary stage of analysis of client's requirements regarding project management, so as to avoid a situation in which during the implementation works, it appears that a wrong system was matched. Software vendors also notice a search for more precisely dedicated solutions, who in some cases, decide to restrict the functionality of the system to a particular industry at the expense of other possibilities.

One of the purposes of this study, described in the previous subsection, is the possibility of its practical application and translating its results into further implementation of PMIS. Therefore it was decided to make a clear separation of the described requirements and functionalities of information systems between industries on the market. The time frame allocated to this work, however, does not allow to take such a broad scope that it was possible to describe specific requirements of all of the industries on the market. A choice was made, therefore, to select these types of projects whose specific requirements seem to diverge most from each other, yet they represent requirements of several similar industries or a market sector:

- construction designs (marked on a spreadsheet as Constr.),
- services sector projects, with particular emphasis on the IT sector (marked on a spreadsheet as IT),
- investment industry projects i.e. investors active on the construction and energy markets, and other investors financing and ordering the execution of projects to subcontractors.

2 The Role of PMIS in a company

This chapter aims to answer the following questions:

- what is PMIS?
- what caused the need to use such systems?
- why are PMIS used?
- what types of PMIS are present on the market and when should an organization consider using a particular type of system?

This chapter provides an introduction to a detailed analysis of market requirements and as such will be maintained at a high level of generality. This means that there will be presented main objectives of the use of this type of IT systems and the direction of further consideration.

2.1 Definition of PMIS

"Project Management Information System [Tool] - a system consisting of tools and techniques used to collect, merge and transfer results of project management processes. Used as support for all aspects of a project from its beginning to the end. Could comprise both manual and automatic systems."[5]

This definition outlines the key functionalities of PMIS. To paraphrase, these systems are a collection of IT tools that allow the use of project management techniques for delivery of process throughout the life cycle of a project.[6]

This definition, although very general, covers the entire functional scope of these systems. It will not be, deliberately, developed in this subchapter, as further elements of the definition are closely related to the types PMIS described later in this article.

2.2 The purpose of using PMIS

Over the past hundred years, many organizations have developed their own methodologies for managing projects, often without using the nomenclature characteristic of modern project management methodologies and this study.

These organizations have developed their own systems of work, which allow effective implementations, peculiar to their industry and business ventures. Such knowledge of the organization is often referred to today as "know-how." This "know-how" was retained in organizations in various forms.

Most commonly it was the knowledge of individuals, personally handed over to further employees. More preventive organizations took care to preserve the knowledge in the form of paper documentation (notebooks, binders, punch card system). Along with technological advancement there is a gradual computerization of companies. It results in saving a number of project data in electronic form and the introduction of successive file formats specific to the data contained in them.

The advantage of project management information systems in supporting project management over their predecessors is in the assumption of the possibility

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[5] Project Management Institute - *PMBOK Guide – Fourth Edition*. Warsaw, Management Training & Development Center 2009, p. 470.

[6] Project life cycle - a division of project into phases in managerial terms. There are usually four to five phases, depending on the methodology. This may be Initiating, Planning, Implementation and Control, Completion as in the case of PMBOK, or Identifying and organizing, Planning, Performance management and Completion as suggested by Harvard Business Essentials in "Managing large and small projects".

of storing all the necessary project data in a central database. This approach, adequately protected from the hardware, software and procedures point aspect, supports the implementation of the following functions:

- knowledge preservation,
- data recording standardization,
- data confidentiality (management of access privileges),
- data integrity (documentation is adequate, complete and up-to-date),
- data availability (data is available upon request),
- facilitated data search,
- ensured data sustainability (assuming maintenance of hardware and software).

To sum up, these systems are used, among others, to organize knowledge about project management in the organization.

In the definition presented in the previous subchapter another basic function of PMIS was quoted, which is appropriate project management support. The IT system, through close links between functionalities supporting various project management processes, can force a user to a sequence of activities consistent with the methodology. A methodical action improves the efficiency of running a project. An example would be a situation when a user, such as a project manager, needs to file a report about the progress of the project with their supervisor. Using an IT system the report can be formatted and generated within a few seconds/ minutes. A condition is, however, appropriate planning of the project according to the needs (detailed project structure, resources, expenses, etc.) in the initial phase of the project, and then providing regular updates on progress of works. In a situation where PMIS is not used, drawing an appropriate report may take up to several hours. During the manual preparation one should reckon with the errors of human nature.

During training and implementation of PMIS one can meet with the opinion (of the more ambitious users) that a properly formatted spreadsheet can be used for carrying out projects. Certainly, running a small project (let's assume a dozens of actions) in this way is possible, however, the lack of predefined functionalities dedicated to the implementation of project management processes makes it difficult. Especially in the course of large projects (a major project is defined as a project consisting of some 500 activities and more, lasting approximately one calendar year and longer), it becomes a very laborious task. This chapter is not intended to define requirements, but it is worth quoting one of the most fundamental thesis to confirm the need for dedicated solutions to support project management. A project schedule changes several times during each phase of the project life cycle, the initial revisions during initialization, subsequent ones during the planning and implementation and a vast majority during regular update of the project and change management. A person executing a schedule update process should have a tool, which on the basis of changes in the duration of at least one action would automatically calculate changes for all activities in the schedule. Otherwise, the updates can be lengthy and involve a number of errors. These errors, in turn, can lead to delays that often result in serious consequences for the project and those responsible for its results.

Another advantage of using a PIMS is the ability to analyze multiple perspectives of the same data, e.g. grouping of project activities through various criteria and a summarizing data according to a specified criteria. The ability to analyze multiple perspectives does not apply to actions only, but also to more detailed data such as resources or costs attributable at their level.

A PMIS is particularly useful when the organization is dispersed among several locations. In this situation, a central database with a standardized method of entering data helps to provide timely information whenever and wherever it is needed. Another advantage is that data is available at each location, immediately after its entry. Other main objectives of using PMIS will be described, depending on the type of system chosen by an organization.

2.3 Classification of PMIS

The following classification does not come directly from any of the methodologies, however, is a result of combining the experience in applying PMIS with the nomenclature adopted by their manufacturers.

- EPPM

EPPM - Enterprise Portfolio Project Management is a system that is based on a central database, shared on a network and enabling data sharing between projects stored in it. An important feature of the system is the ability to analyze data about projects at the level of individual projects and project groups, known as programs[7] or project portfolios[8]. Frequently, these systems have built-in functionalities for conducting portfolio analysis, whose aim is selection.

They are the type of enterprise systems, which are based on the Client-Server architecture, the application is installed on a single machine, which refers to a database working on a server. Most often such a system also has the possibility of access to projects through a browser.

Rationale for the use of a EPPM system:

- many users of the system,
- different levels of access for individual users,
- resource management shared between projects,
- a need for portfolio analysis,
- management is scattered in different locations, departments or even different floors of a large corporate building,
- a need to edit data by multiple users simultaneously.

- PPM

PPM - Project Portfolio Management is a system that can be based on a database, but equally well project data can be stored in files. This follows from the fact that it does not provide data on the network. An important feature of the system, as in the case of EPPM, is the ability to analyze data about projects at the level of individual projects, programs and project portfolios.

Most of these systems do not have the functionality used to conduct portfolio analysis. These are standalone systems, or based on the Client-Server architecture, the application installed on a single machine, which refers to the local database/file system.

Rationale for the use of a PPM system:

- one or a maximum of a few users with a license leased for the time of work with the system (concurrent),
- no need to distinguish between the privileges of users,
- projects are conducted by independent resources,
- a need to summarize data on many projects, but no advanced portfolio techniques are used,
- users usually use the system in one location and do not need remote access.

- PM

PM - Project Management is a system very similar to the described above PPM, but it does not have the ability to summarize data on many projects. In practice, this means that it work on individual, independent files, or storing a number of projects in a database is not able to aggregate data derived from them. Such systems can be divided into two main types:

- legacy systems that do not take into account the possibility of working in a network (often freeware),
- systems dedicated mainly to the construction, design, and energy industries, which are not intended to handle projects independently of each other in terms of the budget, resources, location, and business objectives.

Rationale for the use of PM systems:

- carrying out projects that have exclusive resources, their own budget, whose implementation is independent of other projects of the organization, such as, an office building construction, a part of a motorway, a bridge),
- other points of rationale similar to a PPM system.

- LPM

LPM - Linear Project Management is a special case of PM, a dedicated system for managing linear building and construction projects. Linear projects are all these projects, whose implementation takes place in a large space, often associated with many sq.km. Such projects are building roads, bridges, subways, railways. An important factor that determines the diversity of such projects from others is the use of appropriate resources not only at the right time, but also the right place.

[7] The program - the program is a set of projects. Projects in the program must be implemented in a specific order, which is a condition for *completion of the program.* [Wysocki R.K., McGary R. - *Efektywne Zarządzanie Projektami.* Wydanie III. Helion, Gliwice 2005]. The program implements a number of objectives, centered around the main business purpose such as NASA's space program, a program for building industrial-technological park, the program of preparations for Euro 2012 (author's note).

[8] The project portfolio - the project collection that are closely interconnected [Wysocki R.K., McGary R. - *Efektywne Zarządzanie Projektami.* Wydanie III. Helion, Gliwice 2005]. This definition indicates that the concept of portfolio is wider than the concept of program. Therefore, the program is a special case of the portfolio, and the portfolio may also contain more than one program (author's note).

Hence, the LPM systems are characterized by an additional variable affecting the shape of the schedule and resource estimate, which is the distance at which work is carried out.

- PRM

PRM - Project Risk Management is a system primarily dedicated to project risk management. PRM software is functionally designed to handle primarily one area of project management, and therefore its characteristics differ from other types of systems described in the classification. For this reason, PRM systems will not be the main theme of the study, and during a functional review of PMIS only one representative of PRM will be mentioned. However, risk management is an extremely important area of project management, therefore we have decided to include this type of system in the list.

Rationale for the use of PRM systems:

- running projects with a high level of uncertainty of time, resources, and costs,
- running projects related to the probability of occurrence of events affecting the project, both positive and negative,
- running projects whose implementation is affected by weather conditions,
- running projects whose products are characterized by a low degree of repeatability.

Other points of rationale similar to PPM systems.

3 Analysis of users' functional requirements

An analysis of functional requirements for PMIS will be made based on requirements articulated by clients in the process of obtaining contract, training, and implementation and analytical work[9], derived from delivery of own projects[10] and defined on the basis of project management methodology.

In section 3.1 List of PMIS implementations there is a brief description of implementation, training and projects that are the source of requirements of individual industries.

[9] Training and implementation work on IT projects supporting project management, project documentation, and project risk.

[10] Web application software projects, conceptual design for the architecture for data exchange.

The analysis will be based on the main axis of distribution of project management processes in PMBOK, or on groups of processes reflecting the life cycle of a project. Subsequently, the requirements that will be defined, will be ordered according to their affiliation to the process, implemented under a project life cycle phase. The processes will be presented in terms of the scope of information and activities necessary for their implementation and functional requirements that result from this scope for IT systems. For those of the functional requirements that are derived from specific industries a source of a given requirement will be indicated to an accuracy of one of the organizations listed in section List PMIS implementations and the role in the company, whose owner reported a requirement. This will make it possible to determine the weight of specific requirements for individual industries. Requirements defined in this way will be described using metadata in the following manner:

metadata = [No., requirement, processes group, process, scope, requirement source, weight]

where:

- functionality area of PMIS,
- methodical area of the implementation of PMIS,
- No. - ordinal number,
- requirement - a brief description of the currently described requiremen,
- processes group - one of the five major groups of processes involved in a project life cycle,
- process - one of the activities that make up a processes group,
- area - one of nine areas of project management,
- scope - indication on the part of the process that generates a given requirement,
- weight - subjective assessment of the weight of a requirements for the utility of a system, divided into three main industries:
  - constr. - construction and building industry,
  - IT - information/services industry,
  - inv. - investment industry.

It was assumed that the weight is necessary for the valuation of the functionality to allow for effective evaluation of the solution.

- source of requirement,
- industry - information defining the source of requirement,
- role - position of the employee in the organization who defined the requirement.

Metadata were used to create a table comparing the systems. The Weight field has a direct impact on the results of the comparison. Based on the structure generated during the analysis, a comparison of functionality of selected PMIS was conducted with a breakdown into industries.

3.1 A list PMIS implementations

This section outlines the business and characteristics of enterprises in which carried out implementations or individual stages of implementations, constitute a source of users' requirements for this study.

Professional ethics in the work of a consultant obliges to maintain secrecy in relation to the processes that occur on the client's side and how they are implemented. Therefore, instead of company names contractual ID will be given and business details will be replaced by general characteristics.

Construction and building industry (construction, metal construction, energy):

- company R - an enterprise engaged in construction and support of operation of mines in South America; the main requirement area is risk management,
- company X - a factory delivering metal constructions designs, the challenge was the central database of designs and schedule management,
- company Y - a factory delivering metal constructions designs, the challenge was the central database of designs and resource management,
- company K - a construction company focused on building roads and bridges, the important issue was performance management and location of equipment,
- company W - construction general contractor, the main requirement was the management of documentation and schedule,
- company S - a construction company focused on road construction, work mainly focused on estimating costs and registering their level at different levels of acceptance,
- company P - a construction company, focused on rental of formwork, the primary requirement was to calculate available formworks and their consumption depending on the type of project,
- company L - contract management; the main requirements related to document management and recording of communication within the project,
- company O - an enterprise engaged in designing and manufacturing metal structures (Engineering-Procurement-Construction) implementing projects for the oil sector; requirements related to the majority of solutions described in this study, except the management of stakeholders, documentation and costs.

Investment industry:

- company Z - a construction investor, in the opinion of users, the system was mainly used to control a project development from the management's point of view,
- company I - an energy sector investor, looking primarily for advanced tools of financial analysis and risk management.

Service Industry (IT, services):

- company A (Services - marketing and sales) - a representative of a well-known pharmaceuticals manufacturer, developing schedules and work sheets reporting,
- company B (IT - software development) - a budget unit implementing, among others, IT projects; primarily focused on managing schedules and cost, communication within the team, reporting through data tables,
- company C (IT - software development) - an insurance agency, IT department, portfolio management, long-term resource plan development.
- company D (IT-hardware) - a subsidiary of a corporation responsible for designing and selling equipment on the IT market, schedule management and analysis of resource load,
- enterprise E (IT - software development) - a manufacturer of computer games, synchronization of schedules,
- company F (IT - software development) - a manufacturer of electronic components and drivers for the automotive industry; project plans to manage a team of designers, subcontractors, provide performance qualitative metrics and synchronize design schedules with production ones,
- company H (IT - software development) - a large publishing house, interested in risk management, documentation and improvement of communication in making business decisions,

- company J (IT Consultants - software implementation) - a company running implementations, consulting and training in information systems; building schedules, reporting consultants' work, automatic updates, analysis of loads by hours paid by the client and own,
- own work:
  - Computer Networks - a dynamic web site based on Content Management System (php, mysql, ajax),
  - Designing an Infrastructure for Scientific Communication - a project to unify the data format (theoretical part),
  - Editor's Choice - a dynamic web site (python, mysql).

3.2 Determination of requirements, review of existing solutions and proposal of new ones

During the research were examined 30 processes in 9 areas of project management and across the entire project management cycle to determine 64 user and methodical requirements. The requirements are described based on the practical application of PMIS in enterprises. As a result, not only have the requirements of project-oriented planning and preservation of knowledge after its implementation been considered, but also those associated with implementation of processes groups, monitoring and control. It is the up-to-date progress reporting and change management in a project that may affect the majority of its dimensions which is one of the biggest challenges in the effective use of PMIS in the organization.

Fig. 1 has outlined, at an overall level, an implementation and control cycle of a project using a PMIS, which takes into account the use of work cards. The described cycle can form the basis for making one of several major project management procedures in an organization, and should particular steps should be described with detailed user instructions. These instructions would be created on the basis of the functionalities of the system chosen by the organization.

In response to these and all other requirements there have been defined 220 functional solutions, of which 63 are called innovative solutions. These are unprecedented solution for the tested systems.

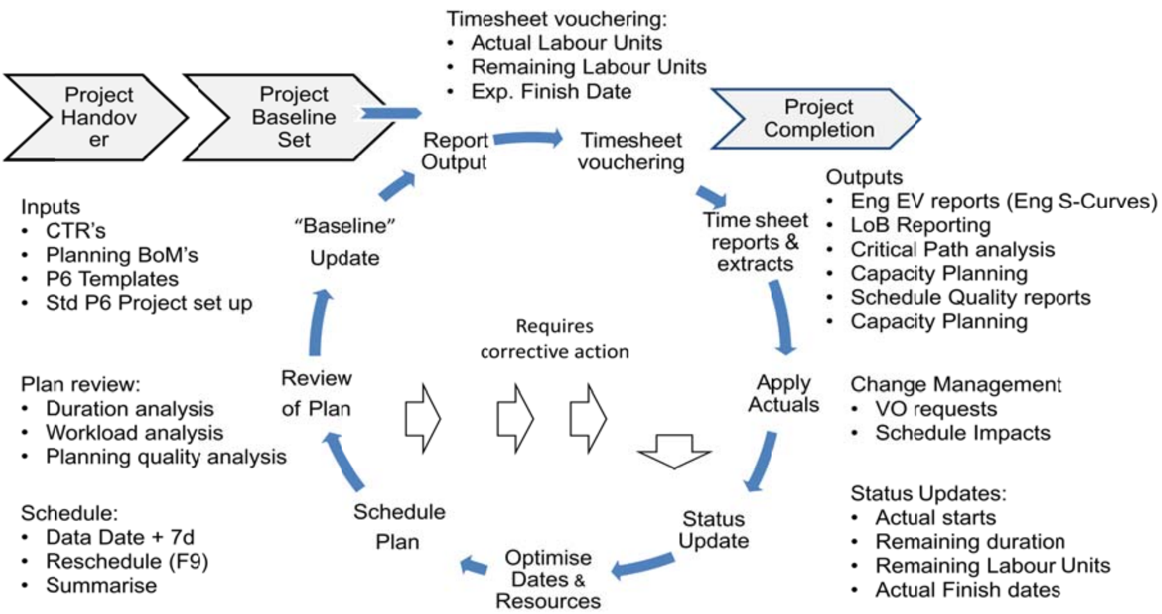

Figure 1. The cycle of implementation and monitoring of the project using a PMIS
(*source: own work based on* [11])

[11] Project Management Institute – *Project Management Body Of Knowledge Guide – Fourth Edition*. Management Training & Development Center, Warszawa 2009.

Limitations associated with the MA thesis framework did not allow comparison of all major systems PMIS on the market. There lacked functional combines i.e. CA Clarity and IBM Rationale, solutions available only through a browser such as @task or Blue Ant and the open source type of solutions with strongly reduced functionality as dotProject and Gantt Project.

However, the tools supplied in Excel spreadsheets allow appropriate extension of the comparison, so that it also included the evaluation of competitive solutions against those presented ones. Systems have been selected mainly on the basis of experience gained in working with them, that is no system testing was involved, whose functional scope was not known. Another selection criterion was to show a range of solutions available on the market, which will show the advantages and disadvantages of different types of PMIS mentioned in chapter four (EPPM, PPM, PM, LPM, RPM).

Eventually, systems selected for comparison are:

- Primavera P6 v 7.0, hereinafter referred to as Primavera P6 and P6,
- MS Project 2010, hereinafter referred to as MS Project,
- ASTA PowerProject v 11.0, hereinafter referred to as Asta Powerproject or Asta,
- Pertmaster (Primavera Risk Analysis) v 8.7, hereinafter referred to as Pertmaster (PRA),
- TILOS v7.0, hereinafter referred to Tilos or TILOS.

Below is a summary of the proposed functional solutions. This summary is intended to provide areas for improvement and problems which the 63 solutions presented in detail in the article are supposed to address:

- Information management through project organizational structure:
  - all communications-oriented functions of the system are powered by the organizational structure combined with a database of users and resources, such as project workflow, issues reporting forms, risk response plan, task distribution lists,
  - supplementing the lack of sufficient authority granulation for the management of the lowest, most detailed part of the schedule which is an action; there would be advisable a level of access to an independent determination of the access/control of the duration, resources, expenses, labels, and individual user-defined fields,
  - storing a complete distribution list of users and resources not being users of the system associated with the project; a table of data would contain information such as e-mail addresses, contact details, preferred channels of communication, frequency of report delivery, broken down into pre-defined categories derived from the organizational structure of the project (project sponsor, managers of the project, primary user, etc.), taking into account their specialization (roles, authority) assigned to each resource (designer, analyst, programmer, etc.).
- Documentation management:
  - defined level of control - access to a document can be controlled:
    - in relation to the project,
    - in relation to users,
  - extended range of authority - access to a document for each level of control is implemented in terms of:
    - document,
    - metadata,
    - authority,
  - limitation of document formats,
  - advanced search after any given parameter among all the metadata and text (with the possibility to exclude any part of them),
  - mass document upload,
  - adjusting the auto-numbering.
- Project initiation workflow administration:
  - workflow templates based on the type of project - the majority of companies specializes in performing various types of projects, such as:
    - the construction and design industry,
    - IT Industry,
    - investment,

    For each type one can imagine different rules for initiating and planning, therefore reflecting procedures could be included in a project management tool which would spare the time of employees and ensured implementation consistent with best practices of the organization.
  - stages of the workflow in the decision tree system,
  - building the workflow depending on the stage of the project,

- history and transparency of the process:
  - ability to track workflow progress by all involved actors in the system, regardless of its stage,
  - ability to track all the decisions regarding an individual workflow that the user was invited to, or access to workflow history.

- Project profitability study:
  - the fields of financial analysis for the tendering stage - a functionality built into the system of fields and comparative calculation methods would enable the team making an offer to operate much more efficiently,
  - parameterized survey to determine the discount rate - incorporating into the mechanism for calculating NPV and ROI, surveys asking questions about selected macro-and micro-economic parameters (current and planned rate of inflation, borrowing rates, the level of investment risk, etc.) would be of great assistance in a proper assessment of the investment,
  - NPVR method - that expanded NPV method described for the analysis of profitability of a single project to the level of the portfolio, provides a ratio that allows objective comparison of expected profitability of the undertaken investment,
  - investment variation - ability to assign multiple budgeting scenarios and investment development depending on the given criteria.

- Stakeholder management:
  - stakeholder register - contains data for the identification of strategies:
    - identification data,
    - information from evaluation,
    - stakeholders classification,
  - stakeholders registry authorities - the ability to define authority enabling access to the matrix only to the project manager and the board,
  - stakeholders analysis - a proposed tool for stakeholder analysis, which is designed to help in choosing a strategy is a matrix, which compares expected benefits of managing expectations of a given stakeholder with the level of its impact on the project; the duly completed data record results in a stakeholders matrix filled with data and in a strategy for dealing with individual cases, which goes back to the matrix by supplementing it with necessary items.

- Management of base plans:
  - a complete baseline plan of performance measurement:
    - ensuring that all (at least most) data from plans such as schedule management, resources, costs, risks, and communication interact with each other and affect both the schedule, cost and scope of the project,
    - recording all the data from these plans in a baseline plan of performance measurement,
    - providing tools that will allow comparison of data from implementation with a defined as a whole project management plan, (data fields, calculations, charts, and fact sheets),
  - baseline plan of early/late dates - a functionality that allows for automatic recording of baselines based on the dates:
    - the earliest,
    - the latest,
    - in between the above two,
  - creating a baseline risk management plan - the ability to create a risk management baseline plan, which would register initial information such as:
    - uncertainty estimation,
    - risk of events,
    - risk register,
  - plan for management of each project risk and their impact on the project.

- Requirements and change management:
  - hierarchical tree of requirements,
  - requirements traceability matrix,
  - workflow changes at the level of activities and work packages (Change Order),
  - unique identification of data editing - any changes and updates would be stored in the database automatically and stored in the historical form with an accuracy of fields editing, which would provide a close insight into control of management of individual actions,
  - integrating the registry of issues with a work plan - ability to determine the impact of a given issue on time and budget of the project,
  - integrating the registry of issues with a base plan - implementation of issues whose category/type

would indicate a change in the scope and would require the user or another person responsible for the introduction of updated baseline plan, which would be a condition for approval of changes (e.g. a change of the status of issues from the category of "Change" to "Closed"),

- workflow integration with the registry of issues - workflow retrieves a change order from the Registry of change orders, and returns at least change status such as "approved", or directly affects the parameters of the project,
- workflow templates depend on the type of change - examples of the types:
  - change in scope of work,
  - change of budget,
  - change of dates schedule,
  - integrated project change,
  - problem,
  - request,
- automated control of WBS version,
- automated renumbering when changing the struture.

• Resource management:
  - load the resource limits of the project - this feature would be intended to designate the limit load the resource at the project level and, consequently, to calculate the limit of the project with currently available resources,
  - automatic updating of the work limit,
  - improving the calendar integration - in PMIS there are numerous calendars at different levels of management, such as a system calendar, project calendar, action calendar, resource calendar; the proposed improvement is to create an algorithm for calculating the duration, which will be clear even in complex cases; if not all combinations of calendars can be handled in a logical way, the system should prevent or warn against their use which will significantly facilitate the use of the right combination and will saves a lot of time,
  - setting permissions to assign a resource at the project level - assigning authorities to resources:
    - at the project level,
    - at the level of a single resource,
    - at the level of editable labels/codes of resources,
  - improved search of qualified resources,
  - a summary of long-term planning against the detailed one and their execution - a detailed summary of load charts presenting the level of work-hours consumption (for the construction and building industry there should be added the possibility of long-term planning of equipment use) over time, in terms of values planned in the long- and short-term and the actual curve would be a clear and valuable management information.

• Methods of schedule building:
  - Critical Chain Project Management (CCPM) - proposes improvements in the following areas:
    - introduction of resource buffers functionality,
    - matrix of buffers use,
    - proposing an automating (proposing) mechanism for the transformation of early deadlines schedule into the deadlines schedule,
    - proposing a mechanism for resolving resource conflicts,
  - advanced multivariate analysis - the curves would present a distribution of duration, costs and man-hours with the possibility to activate their view or exclusion from the analysis, and the calculation and marking on the graph a difference between the displayed variants,
  - extensive cost analyst,
  - advanced expenditure management,
  - managerial reserves management,
  - Delphi technique - this functionality would make it possible to assess the duration of individual users with the option of recording their history and comments justifying estimations; the results would be presented in a table, and histogram.

• Risk management:
  - the system of authorities for risk management,
  - integration of EPPM and RPM.

• Supplier management (a list/register of qualified suppliers):
  - separation of resource type for subcontractors,
  - combining information about the assignment and subsequent execution of the order with the structure of subcontractors (baseline, subcontractor performance, compliance of performance with objectives),

- possibility of defining any user fields for the sub-contractors structure.
- Project implementation analysis:
  - analysis of the duration reserve:
    - indicator of total reserve consumption,
    - indicator of total reserve,
    - indicator of buffer packet consumption,
    - indicator of packet buffer,
  - user support - understanding the source of results calculated by using the EV method and their interpretation, poses such difficulties to organizations that even experienced managers are often afraid to use the method,
  - analysis of trends in progress (Forecasting) - graphical analysis techniques should support recorded in the trends register data on the progress and estimations at various stages of the project,
  - comparison of variants of the analyzed variations - at the implementation stage a particularly useful would prove a feature that would allow a clear comparison of results of different calculations used - present used settings in a table, compare them with charts that would illustrate the differences between the curves of the EV method.
- Quality management:
  - technical performance record (technical performance measurement) - a register of quality keeping the results of analyses performed using the tools described in the study; the register should allow periodical data collection and their collation in aggregate reports,
  - block diagrams - a visual representation of the process, which shows the relationship between the stages, shows the action, their sequence and decision points,
  - Run Chart - a chart of performance used for the quality metrics analysis,
  - Ishikawa chart (cause and effect),
  - Pareto-Lorenz Chart,
  - extended schedule evaluation (Project plan quality review) - out of the tested systems, analysis of the logic of the schedule has not been developed to the limit, as shown by Patterson D. [6] .
- Reporting:
  - work-card team reporting - an improvement, which could increase the use of the solution would be to report work hours by foremen for all their subordinate team,
  - reporting using work cards divided into categories of hours - it is important, in terms of the financial settlement of the project, to divide the reported hours into billable/applied) and non-billable/non-applied; billable hours are those used from the project budget, for which the client pays; the non-billable ones will be paid by the organization from its own budget,
  - enhanced methods for graphical reporting - a possibility to build curves and other types of graphs described in the study, on the basis of project data, also from the level of user-defined fields,
  - tracing users activities (Repository of reports) - the possibility to demonstrate the activities of users within different elements of the project; this feature allows to build individual responsibility for activities undertaken within the system,
  - a set of closing reports:
    - project completion report,
    - project evaluation report,
    - experience report,
    - integration of methodologies database with project database.

4 Comparison of existing functional solutions of PMIS

4.1 Purpose and nature of the comparison

Objectives of comparison:

- Choosing a system best performing requirements for specific areas of management. The motivation for this kind of comparison is the fact that often organizations, even from the same industries, manage projects in other areas and give up other areas of management. Therefore, a potential reader of this comparison will be able to choose a system that best matches the requirements in their industry, in their areas of interest. In order to be able to perform a constructive comparison of the various areas, certain resource management processes in the area of integration management (long-term planning) and the area of time management (activities resource assessment) has been moved to the area of resource management (moved requirements are marked in the Requirements qualification tab by yellow background).

- Selection of the most versatile PMIS, which in the next step will serve as the basis for the development of the missing functional solutions, in relation to competition, and the new proposed ones.

The comparison should be of as objectively as possible. However, total experience of each consultant or user is different and probably largely depends on the nature of the various implementations in which they had the possibility to participate. Taking this into account, it was decided to adapt the form of analysis to user needs, and although the article presents unambiguous results, will allow to assign own industry weights, % weights of implementation of the process and evaluation of solutions for individual systems, dependent on the experience of individual users. The goal is that anyone interested can take advantage of the tool prepared for this study and be able to adapt he comparison, if they assess a solution differently.

The flexibility of the tool prepared in this way will also be of key importance in the case of testing newer versions of a system, which at the time of writing this article are available for some of the tested ones, such as Primavera P6 v8.0 or Asta Powerproject v12.0.

4.2 Summary and evaluation of the functionality of selected systems

Assumptions to make the comparison:

- any functional solution is the answer to a specific requirement assigned to a particular process; both the requirement for a functional solutions and the process in relation to the requirement are linked by a one-to-many relationship,
- each functional solution is evaluated in the scale of 1-10 for each system regardless of the industry,
- each solution meets the functional requirements for the process to a certain extent (percentage), which means that all of the functionalities within a single process add up to 100%,
- the above implies that, regardless of the number of functionalities in the process, each process affects the final general assessment to the same degree (however, not every area will have the same weight as each area may have a different number of separate processes),
- each functional solution receives a final assessment (weighted rating for the sector), resulting from the multiplication of the following values:
  - weight for the industry,
  - % share in the process,
  - absolute assessment of the functional solutions for a given system,
- points accumulated by individual solutions are aggregated to the level of management areas and to level of the general assessment,
- the results are presented using Tornado graphs which represent each system as a single horizontal bar, where the length of the strip is greater the more points the system received in a given area for a given industry; such presentation allows to compare systems in several dimensions:
  - assign places (priorities) to systems based on the number of points scored by them,
  - present a difference in the advancement of functional solutions by the difference in the length of the bars (not only 1st and 2nd place, but also a difference between the systems),
  - point score on the horizontal scale will illustrate how many and how important solutions were used in different areas - the larger the more important functional solutions,
- additionally, pie charts were used to illustrate the weight that individual systems attach to different areas of project management; the value was calculated based on average points scored by a system in various industries in a given area.

In Fig. 2 in the area of integration management one can see the overwhelming dominance of Primavera P6 v7.0 system over the others.

This is mainly thanks to the rich functionalities provided to the user at the beginning and closure stage of a project as well as the application of great importance to the functionality of issues management, which serves as a registry of change orders.

Nearly as good are MS Project in the IT and Service industry, and the investment one, where a greater importance, than in the construction and building industry, is placed on mechanisms of the workflow type, which are plentiful in the system.

Figure 2. Summary of scores achieved by the tested systems in the area of integration and scope management (*source: own research*)

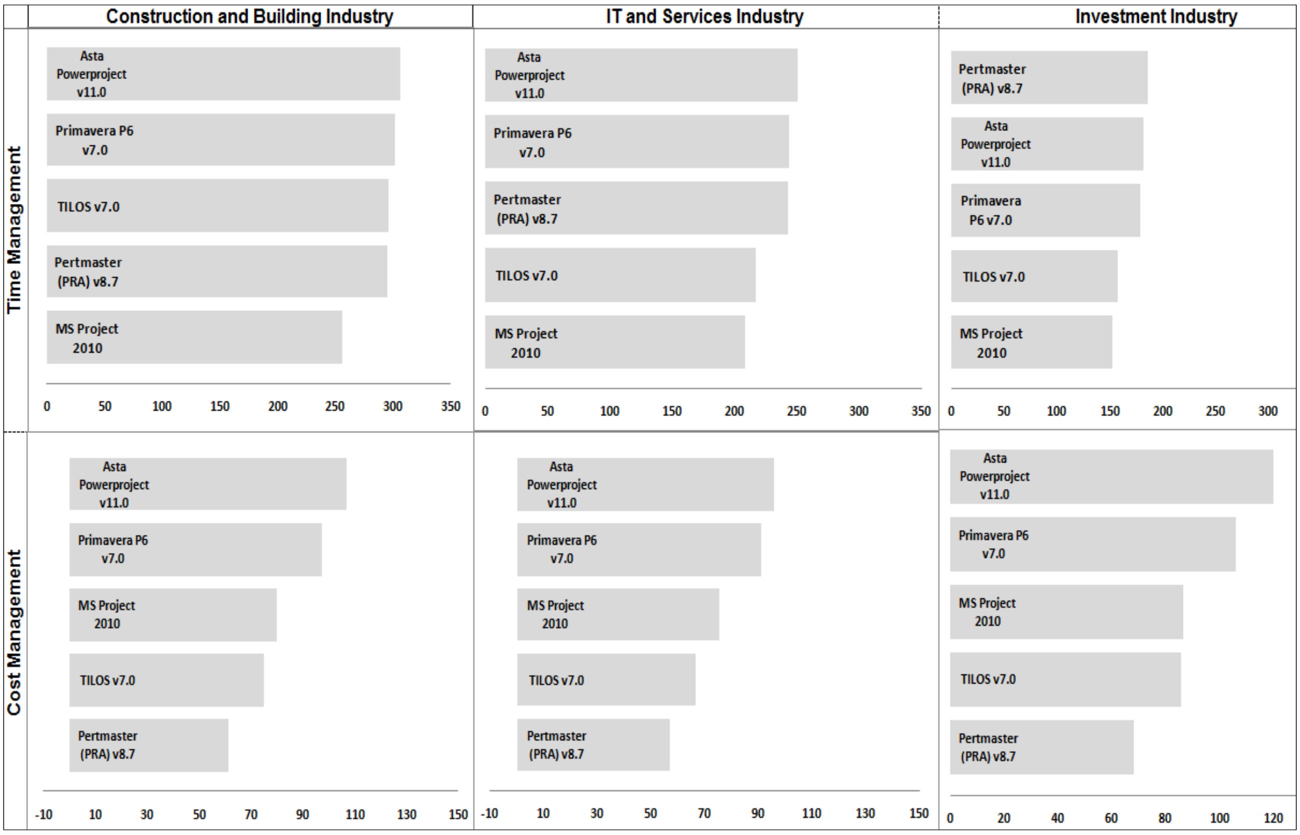

Figure 3. Summary of scores achieved by the tested systems in the area of time and cost management (*source: own research*)

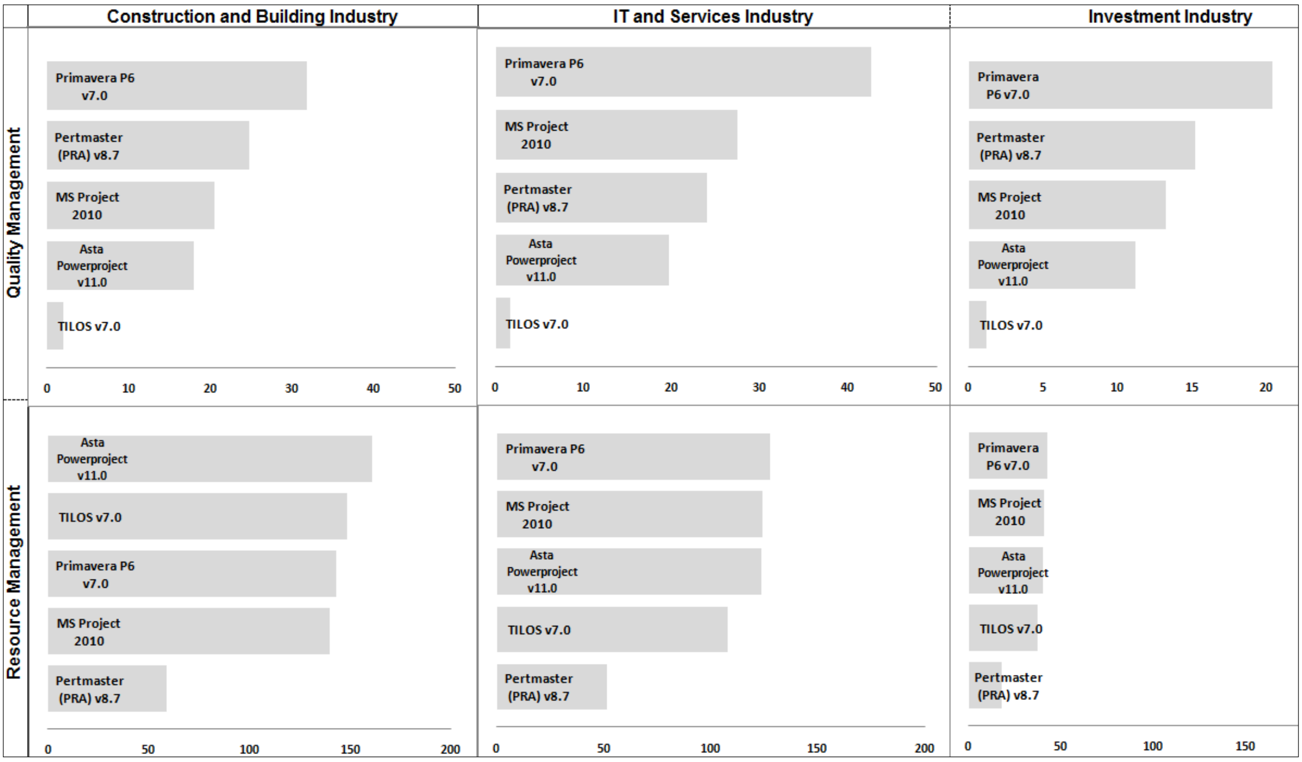

Figure 4. Summary of scores achieved by the tested systems in the area of quality and resource management (*source: own research*)

Asta Powerproject wins second place in the construction and building industry due to advanced functionalities in the area of project management plan development and project management, well suited to this industry.

Within the scope management P6's advantage is no longer so clear, and was achieved by best-in-class mechanism for creating a work division structure - relatively easy to use and clearest.

Fig. 3 shows high scores obtained by all systems in the area of time management, which is not surprising as that is an area used independently of other factors by all users.

Asta Powerproject wins by advanced functions of building and presentation of the schedule, which are often innovative in relation to the competition.

It only gives ground to Pertmaster (PRA), which gains an advantage in areas where advanced feature of schedule building are not absolutely necessary, that is in the investment industry. Pertmaster's strengths (PRA) are primarily the possibility of advanced estimation of the duration and building a probabilistic schedule and the possibility of its analysis with a Gantt diagram, which gives a good visualization of uncertainty and risk events as well as by using statistical graphs.

Primavera P6 presents a solid functional range, and TILOS dedicated only to the building and construction industry shows its advantages by taking third place.

Asta Powerproject is a leader in the area of cost management, its functionalities allow for the most detailed description of the nature of the project expenditure. Asta also allows to record revenues. Primavera P6 makes up for its deficiencies with best practices in the field of earned value management and a clear presentation of data.

Fig. 4 shows the advantage of Primavera P6 in the area of quality management, because it can summarize data at the level of a project by a number of graphs that can be used to make a technical measurement of the project.

In this respect also Pertmaster (PRA) and MS Project do well, the latter especially well in the IT industry thanks to a good service of iterative works (review). There is a clear division into industries within the resource management, where Asta and TILOS do well in managing equipment and materials by providing a base of standards and mechanisms calculating quantity surveys.

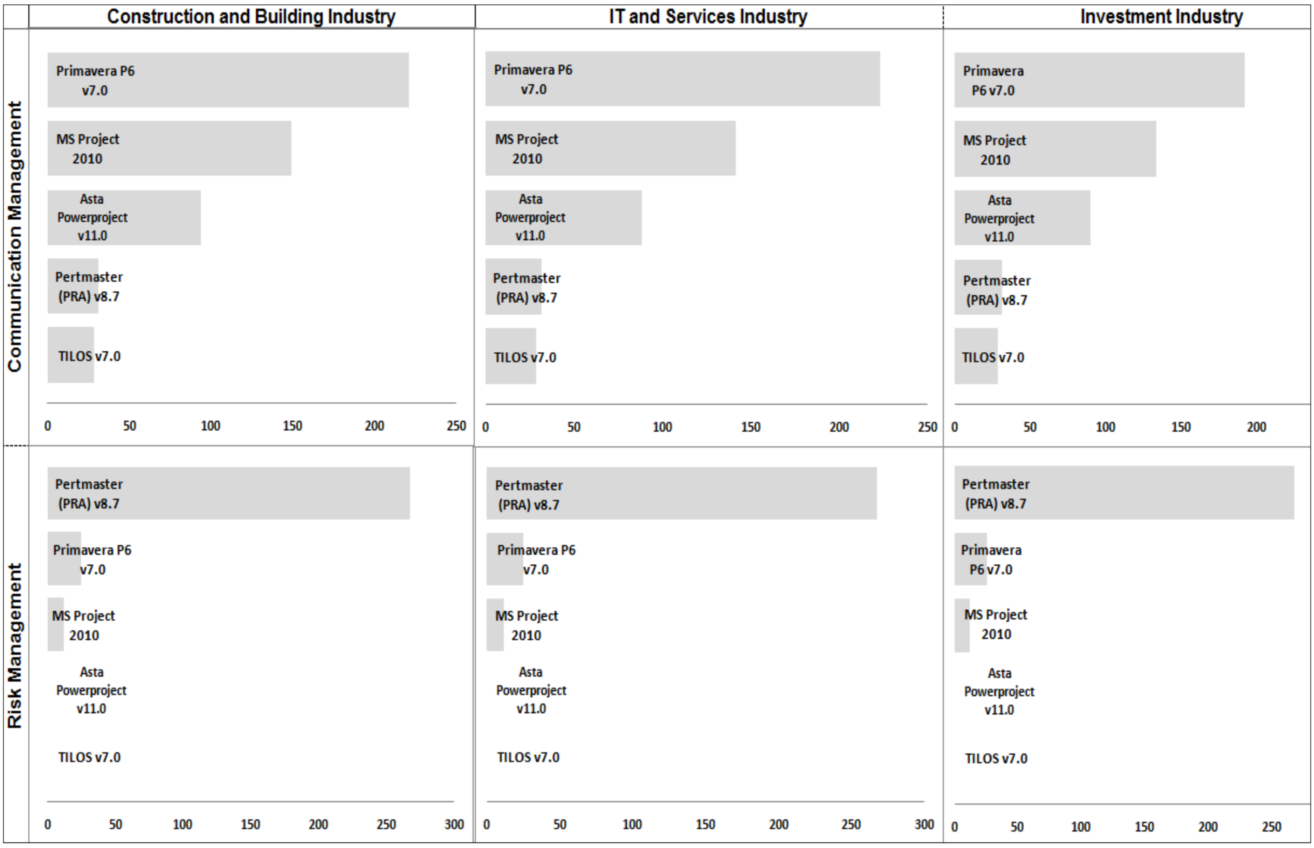

Figure 5. Summary of scores achieved by the tested systems in the area of communication and risk management (*source: own research*)

Primavera P6 and MS Project gain a minimum advantage through long-term resources planning in other industries.

Communication management (see Fig. 5) is largely dominated by Primavera P6 due to the highly advanced reporting capabilities, document management, and the function of determining and reading the project's organizational structure, available also at the level of work breakdown structure.

In the area of risk management Pertmaster (PRA) is second to none, both due to a highly advanced risk management module, but also due to the incompetency of competitors in this field.

Traces of risk management can be found in Primavera P6, while the points awarded to MS Project are the result of the presence of a registry, which, however, has no effect on the project plan.

An attempt was made to choose the best solution for each of the industries, however, this result should be treated as pictorial rather than as a real indication in selecting a PMIS.

This is due to several factors:

- the result is the sum of solutions in all areas, while very rarely end-users use all, and certainly not all of them in the same way,
- some systems are dedicated to a narrow range of use in projects, but due to the specialization in these narrow applications they are next to none. An example would TILOS be for individual linear projects, or Pertmaster (PRA) for risk management,
- the score was awarded taking into account the wealth of multiple projects management in a central database and options for restricting users' access to parts of projects and editing options, therefor systems like TILOS or Pertmaster (PRA), by definiton, scored lower in certain requirements. It should be noted, however, that often companies use joint solutions such as EPPM combined with RPM or LPM systems.

Summing up the results of comparison in Fig. 6 and Fig. 7, one can see that the most versatile of the tested systems is Primavera P6, the least - TILOS.

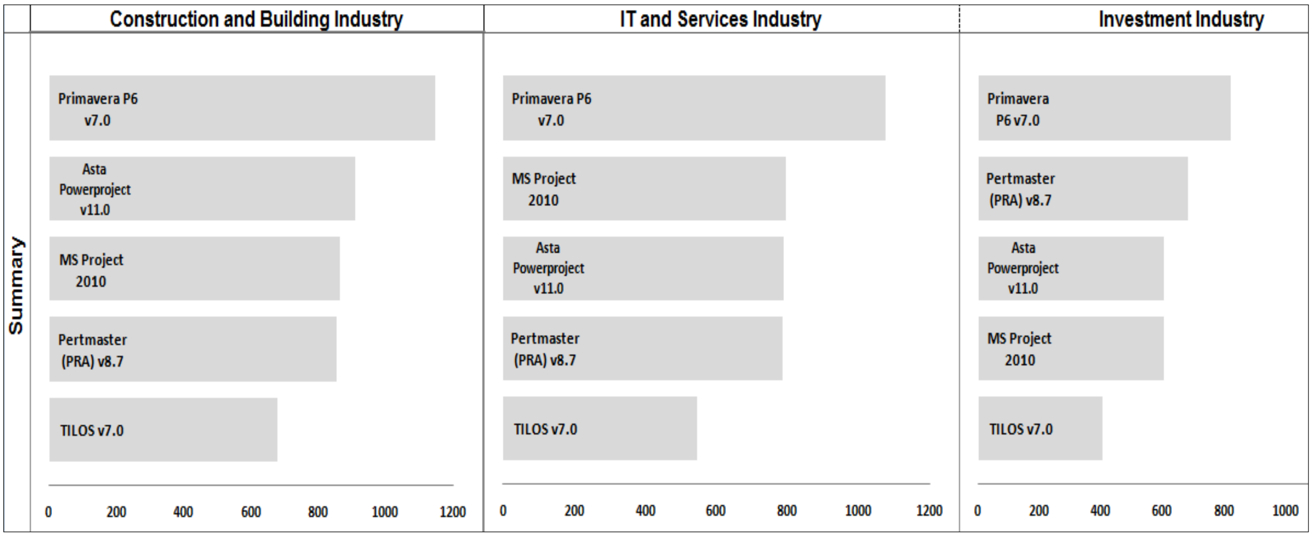

Figure 6. The combined results achieved by each of the systems in respective industries (*source: own research*)

Asta Powerproject is strong in construction and building industry, and in fact its dedicated functionalities for this sector often, more than any others, determine the choice by the users.

MS Project, which is the most popular choice because of its price and distribution system, is created by the manufacturer with the IT and services industry in mind, excluding many important solutions for other industries.

Compared with Primavera P6 it is still in its infancy as a network solution and much more impressive is the version of MS Project 2010 Professional (than MSP 2010 Server), which introduced a few interesting innovations to the market, particularly in the management of human resources.

Pertmaster (PRA) wins where the main focus is on the risks and taking into account the pie chart showing the share of functional solutions in breakdown into areas of management, this should not be a surprise. The following chart of Pertmaster (PRA) as well as other tested systems, shows the share of functional solutions in a given area in relation to all that have been presented for a given system in this study. This means that one cannot compare these graphs with each other, only the areas within a single system.

5 Summary

Described above comparison of systems is one of the products of the study. It was assumed, that it is impossible to propose improvements in project management using information systems, without a detailed diagnosis of their abilities. The second product of the study is a list of those among relevant functional solutions that are found only in some systems, and may be important to strengthen the position of the manufacturer on the market in the event of implementation of their system. These solutions were rated 9 or 10, while other systems for the same solution received 0 rating.

Third important product of the study are offered innovative functionalities that provide the answer to some of the requirements from users of PMIS. Their innovation lies in the fact that none of the tested systems features them, and they can provide significant advantages in project management. How can this be measured? A similar method was used as in the comparison of existing solutions. Details are presented below:

- an assessment of the impact of innovation on each of the areas of management,
- within the area of management the results were divided into industries,
- results were illustrated by graphs showing the percentage of the weight of innovation in relation to the weight of the existing functionalities described in the study,
- weights are derived from the main table called Comparison of solutions in which every solution received weight for individual industries, which was multiplied by % share in process implementation.

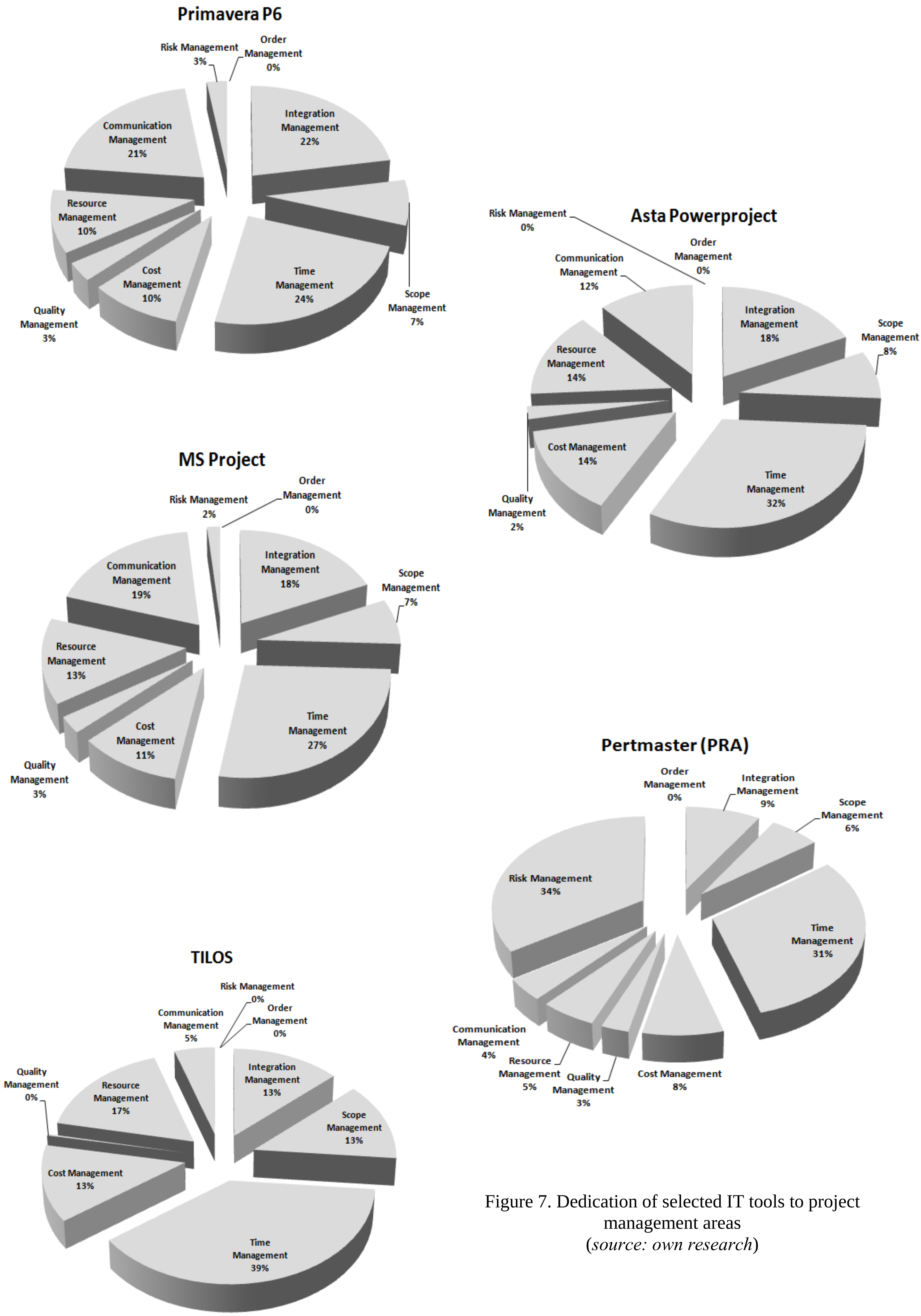

Figure 7. Dedication of selected IT tools to project management areas
(*source: own research*)

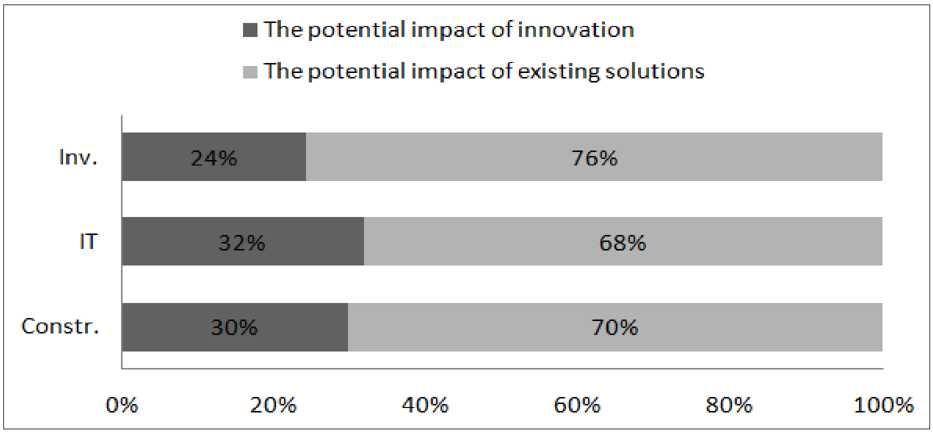

Figure 8. Combined summary of the potential impact of new solutions on industries (*source: own research*)

As a result of employing this methodology, results were obtained for the various areas of management.High development of selected areas of project management in PMIS, such as time management in all the tested ones, or the risk management in Pertmaster (PRA), result in the fact that the proposed innovative functionalities do not have a decisive shape over the system capabilities in a given area of the project. The opposite of this situation is the area of order management, for which it was concluded, that there is lack of dedicated functions (although there are support functions) among the tested systems. Therefore, suggesting a fairly complex function in such a significant way affects individual industries.

It is worth noting that most of the areas achieve significant potential functional growth compared to the original. A smaller impact is noted by already highly functionally developed areas of management in at least one of the tested PMIS, such as:

- time management,
- resource management,
- risk management.

Final average results of the impact of innovation are at a level just under 30% which (see Fig. 8), taking into account the functional complexity of existing solutions, should be considered a satisfactory result. This result should all the more be of interest to software vendors when all these functional solutions are added, which a system of a given vendor does not have, but are present in a competitor, and match the profile of the target group of clients.

The results of this study should provide value for:

- system users, since it fits their industries and management areas most important for them,
- software vendors, as they will be able to review the strengths of competition,
- software vendors as they will be able to review user requirements in terms of solutions missing on the market (or at least on a large part of the market),
- consultants and others parties interested in standardizing project management employing IT solutions,
- methodology developers who have a chance to see that resource management does not apply to human resources in projects only, and that projects worth paying attention to are linear projects, because for both management techniques require advanced planning.

The presented study may constitute a starting point for an in-depth analysis within the "Compendium of good practice for implementation of PIMS".

This analysis would include practical examples of implementations and application of different tactics depending on the size, industry and involvement of organizations in implementation. An example of such tactics might be purposeful coupling of work cards functionality in PMIS in the IT and services industry with a financial module of ERP system, settling reported work hours. Such an integration may be crucial for the motivation of project managers and teams implementing projects to implement a project management methodology by an IT system standardizing the work.

Another element that could enrich the study work would be a chapter dedicated to the functional requirements and solutions supporting project management called "Requirements across management processes", which could include functionalities aimed at:

- managing multiple projects (IT functions and functions corresponding to requirements defined in the theory of portfolio management by Henry Markowitz),
- administering global system data (authority, global data structures),
- adapting functions of data availability (limited view of unnecessary functionalities for users with limited privileges),
- tracking user activity,
- functions of integration with other applications (export/import, API, SDK, Web Services),
- functions of action adaptation (internal functions, Excel Asta and Pertmaster (PRA) macros).

Based on research of these topics it could probably be possible reach further conclusions regarding functional solutions on the borderline of IT and management, whose implementation would be a real support for the business. This follows from the fact that it is impossible, in any organization implementing a PMIS, to avoid the following topics:

- limiting complexity of the system for certain users,
- integration with other business applications,
- possibility of easy functionality increase through VBA, and user activity tracking, building accountability for actions within IT systems.

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PROCESS APPROACH TO KNOWLEDGE MANAGEMENT

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Abstract: The article points out the limited availability of practical implementation guidelines, methods and tools as one of the core issues in the widespread usage of knowledge management (KM) in organizations. The process approach is proposed as an efficient way to understand the scope of knowledge management and to plan its development or improvement, in line with organizational strategy. The role of information technology (IT) in supporting knowledge management is emphasized and key functional groups of IT systems are listed. A sample section of the detailed process model is presented for the KM resource identification master process, with a BPMN graphical visualization. Both the process model and the detailed specification of IT systems supporting knowledge management are considered by the author as complex structures that require to be hosted in a dedicated support environment. Key assumptions of a tool, named KMBoost, are outlined to show how a simple, but interactive toolset can foster the understanding and usage of the KM process model. In the concluding remarks a high level SWOT analysis of the KM process model and the KMBoost tool is conducted.

Key words: organizational knowledge, knowledge management, knowledge activities, knowledge management model, process model, process hierarchy, process approach to knowledge management, process visualization, business process modeling notation (BPMN), process evaluation and scoring.

1 Foreword

The concept of knowledge management (KM) receives constant attention from the world of science, mainly in the area of organizational management and information systems. This attention is well reflected in the number of publications and information technology (IT) solutions or development platforms available on the market[1]. The potential benefits of proper knowledge management are very appealing, as they influence all dimensions of the balance sheet and the profit and loss statements[2]. The promise of higher revenues, lower costs as well as the optimized capital and resource structure is hard to reject by contemporary managers, pressured to deliver strong bottom-line results, despite turbulent economic conditions.

In the world of business it is rather easy to identify organizations that either consider themselves as "knowledge based" or undertake various initiatives aimed at addressing knowledge issues. Such initiatives usually involve an introduction of specialized technologies, designed to better support the organizational life cycle of knowledge. Technology implementation projects are typically expected to bring breakthrough performance improvements, serving as a universal and comprehensive remedy for a wide range of knowledge management topics. The research of L. Prusak[3], conducted on the population of 220 IT projects in knowledge management, shows that at least half of these initiatives failed to meet their objectives, mainly due to the disconnection between the system features and the strategic agenda (Bergman [2], p. 2). Since the ultimate goal of knowledge management is to support the execution of the strategy adopted by the organization, KM initiatives that fail in this respect may be considered a waste of time and resources.

The study of literature hardly provides any evidence or opinions that knowledge management in general is not worth pursuing. At the same time, it is not easy to find practical guidelines, methods and tools that allow for organizations to comfortably embark on the knowledge management journey. The potential of knowledge management is recognized and praised, but its scope and the implementation path remains unclear, often being dangerously simplified and reduced

[1] The author conducted a study of IT systems that were being classified as "supporting knowledge management". Already in 2007 the list included 1170 solutions that offered support for selected KM activities.

[2] Based on the authors' research, the highest impact is expected with respect to the optimization of costs.

[3] The Director of the IBM Institute for Knowledge Management. Source: http://www.ibm.com.

to the introduction of a technological solution[4]. In other words, the key issues today seem to be the "what" and "how" of knowledge management. One may say that the "what" is not questionable as there are many definitions of knowledge management available[5]. The definitions however are insufficient, if they are not followed by practical, proven and detailed methods and tools[6]. Obviously, the better we define "what" the content of knowledge management is, the easier it is to define the "how" part of it, in the context of an individual organization.

Based on the research on the definition of knowledge management[7], the author concluded that 70% of definitions specify KM as a process or a set of organizational activities. There were 234 descriptors used in the definitions, with about 70% related to knowledge: creation, usage, identification, sharing, acquisition, organizing and capturing. The study showed that the mainstream archetype of knowledge management has a process nature. Such a situation justifies the usage of the process approach to analyzing knowledge management ("what") and to developing practical implementation solutions ("how"). This paper provides a proposal of a process model of organizational management, together with a view on how this model can be used by managers who target a systematic approach to improving the KM system in their organizations.

2 Process Approach to Knowledge Management

The process approach to business engineering has its historical roots dispersed across various sources and management schools. Putting the history aside, the plethora of opinions on process management is solidified and organized under the ISO 9001 standard[8]. ISO9001 states that organizations should be viewed as a series of interlinked processes which must be identified, described, marked with performance criteria, measured and last but not least - improved, in a continuous fashion. This approach was widely adopted by leading manufacturers who concentrate on the quality gains possible to achieve via process thinking combined with a detailed statistical analysis of performance[9]. Process analysis is also the methodological foundation for consulting companies, that happen to be some of the most advanced knowledge based organizations.

One of the key success factors in usage of the process model, internally or in assisting other companies, is the drive to understand the complexity behind the organizational activity. As the inscription on the Delphi Oracle states[10] - *nosce te ipsum* ("know thyself") - understanding ourselves is the true key to predict one's future. The process approach places special attention on the understanding of "what" is being done, in order to propose a better way on "how" to do it. Such an explanation might sound trivial, but in fact its simplicity can be seen as a significant advantage. There are usually no golden, universal solutions that can be applied to any organization. That is why we must dedicate enough energy to the understanding of the organizational processes in order to identify the true value chains and focus on their optimal design.

As described in the introduction, knowledge management can also be considered a system of interlinked processes. By compiling various popular and specialized[11] views on knowledge management, and building upon the process model of G. Probst [15], the following definition of KM can be proposed: knowledge management is a systematically organized and integrated set of processes, aimed at the optimal usage of knowledge resources, in a broadly defined decision taking.

The main processes of knowledge management include:

- knowledge resource identification,
- analysis of knowledge resource usability for the organization,

[4] IT failures due to misunderstanding of processes also highlighted in ([11], pp. 12-14 „Principle 5").

[5] In a brief research exercise the author easily collected over 100 various definitions of knowledge management.

[6] Author's view is fully in-line with the opinion of A. Buono, about the mismatch of theoretical work and the actual needs of business operators ([3], 2000, eBook - Chapter 14).

[7] 68 definitions of KM were selected for a detailed, semantic study to identify shared and specific elements.

[8] International Organization for Standardization (www.iso.org).

[9] E.g. the Six Sigma or Lean concepts.

[10] Source: [1].

[11] In the „popular" category we place concepts such as the widely discussed "spiral of knowledge" of Nonaka/Takeuchi [12]. The less popular, but very interesting views include the work of M. Nissen on the knowledge cycles [11].

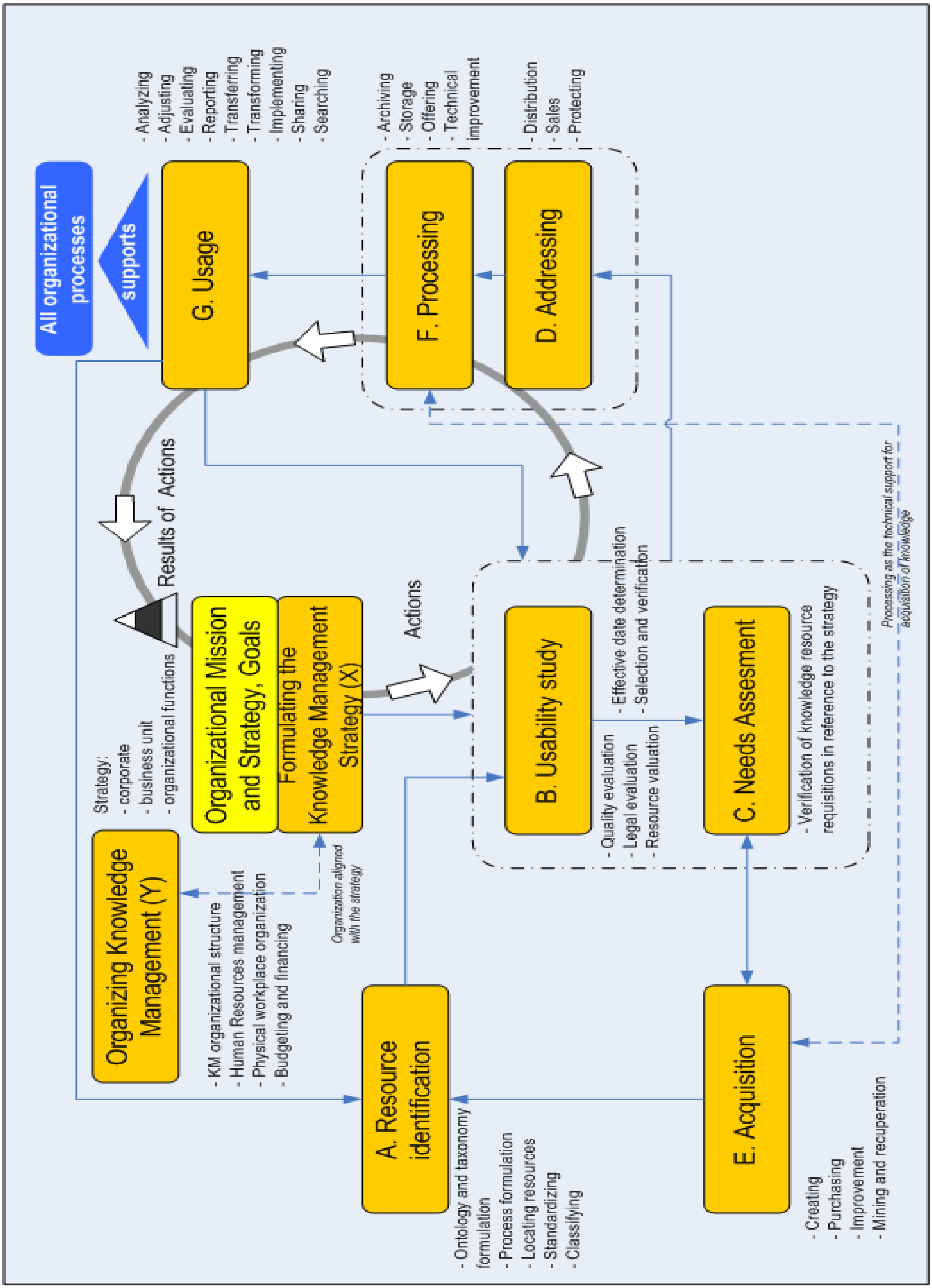

Figure 1. Key processes in knowledge management
(source: self study)

- analysis of knowledge needs/requirements,
- addressing of knowledge resources,
- acquisition of knowledge resources,
- processing of knowledge resources,
- usage of knowledge resources.

It is important to mention that in this view we emphasize the role of verifying the usability of knowledge resources and the necessity to study the knowledge needs of an organization.

These two elements, not explicitly seen in other models must not be overlooked, as we can easily find examples of organizations that consume their energy on either processing of knowledge that is no longer needed or generate knowledge resources in separation from the needs outlined in the strategy.

A graphical representation of the above definition (see Fig. 1) is enriched with a network of flows or relationships between the main processes of knowledge management[12].

In addition to the seven key KM processes, the diagram contains two additional processes: formulating the knowledge management strategy (X) and organizing knowledge management (Y).

These two processes are not specific to KM and are shared with other areas of organizational activity, such as production, client service or human resources management. All of the elements of any human activity must have their individual strategy (linked to the overall mission, strategy and goals) and must be properly setup by organizing the necessary resources, tools and systems as well as processes and procedures. The X and Y processes are therefore added only to complete the setting of knowledge management within the organizational context, but they are not subject to a detailed discussion.

The starting point of knowledge management is the transformation of the organizational mission, strategy and goals into a clear knowledge management strategy. The three key processes that are linked to the defined KM strategy are resources identification (A), the usability study (B) and the needs assessment (C).

Once the KM strategy is formulated, an organization needs to find answers to the questions of "what do we need", "what knowledge resources are already available" and "how useful are the current resources to support the strategic direction". Taking into account the dynamic market conditions that influence most organizations on global and local markets, the demand for knowledge resources is very high and subject to frequent changes. The necessity to remain adaptive to environmental changes is one of the reasons behind the inability to maintain the equilibrium between the resources held and the actual needs.

The efficiency of interaction between the A, B and C processes has a profound impact on the remaining elements of the KM system in an organization. The needs assessment triggers knowledge acquisition processes (E). At the same time the identified (A) and useful (B) resources are being addressed (D) to the organizational units and further processed (F) and used (G) in all activities of the organization, leading to the execution of the strategy. If the processes of identification (A), usability study (B) and needs assessment (C) are not properly managed, it is possible that the organization will be operating without the necessary knowledge resources, while simultaneously dealing with resources that are not needed to execute the strategy. Taking into account the high cost of knowledge resources (human capital, systems and tools), it is very important to assure that all units "get what they want" and "want what they get", focusing on value generation and not maintaining legacy, redundant knowledge resources.

The diagram also shows a number of feedback loops that link the processes by providing a higher integration of knowledge management. For example the usage of knowledge resources (G) might lead to discovering some resources that were not located by the identification process (A). Usage (G) is also a sanity check of usability (B), verifying the quality of resources and possibly proposing their delivery in another form (e.g. aggregated, analytical, available more or less frequently).

The proposed model of key processes in knowledge management provides a solid, high-level base for defining the scope of KM. It is a theoretical framework upon which we can build a practical view of what knowledge management truly is. High level descriptions of KM are omnipresent in publications, but they do not support organizations in the implementation or improvement of their KM systems.

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[12] This representation may be considered more pragmatic as compared with other models, where the principal set of relationships is described as "many-to-many" set between all key processes.

The most natural way to define the detailed scope of knowledge management is to describe the next levels of processes, attached to the main 7 processes of knowledge management, as described above. This further decomposition allows to move the discussion to the level of activity groups that can be recognized by managers as something they already perform or should possibly start practicing.

In addition to the pure identification of detailed knowledge management processes, the detailed analysis also allows to capture the relationships and dependencies existing between KM components, as well as the flows of artifacts and knowledge resources.

3 Detailed Map of Knowledge Management Processes

There are several primary challenges related to the definition of a detailed map of knowledge management processes. First of all the availability of existing publications and research that reflect a similar detailed view on KM is limited[13]. Second, knowledge management is very tightly linked to the applications of information technology (IT) and as such cannot be analyzed without a good view on the functionalities of IT systems and solutions commonly used. Then we cope with the issue of organizational variety and the ability to provide a standardized view on knowledge processes regardless of the type, form, purpose, size, composition or other morphological features of an organization. These challenges provide a strong stimulus to develop a detailed process model that might provide valuable insights into the process nature of knowledge management.

The detailed KM process map can be developed by combining various available information sources and experiences into a single process framework, following the high level outline of key knowledge processes, presented in chapter 1.

Based on this outline, a method used by the author covered 5 steps:

1) selection of a notation to document the KM processes, based on available process graphing and visualizing standards,
2) first view on KM detailed processes, based on self experience and overall literature studies,
3) semantic analysis of KM definitions and models, mapping of KM activities,
4) combination of results of steps 2-3 with the output of the IT systems study to form a final, detailed process map,
5) development of process diagrams to reflect the relationships between processes on levels 1 and 2 of the hierarchy.

In step 1, the Business Process Modeling Notation (BPMN[14]) was selected over other choices (such as the Unified Modeling Language/UML or the Extensible Markup Language Based Process Definition Language/XPDL). The selection of BPMN was mainly due to the ability to reflect the desired level of detail, focus on the business perspective (not IT oriented), relative simplicity and overall compliance with other standards, allowing for further development of any process models built with BPMN.

A first list of sub-processes was compiled in Step 2, already showing over 100 processes linked to the 7 key KM processes. In step 3, a semantic analysis of 68 knowledge management definitions and 10 models was conducted to develop a list of KM activities, understood as processes on various levels of the process hierarchy. A total of 396 KM activities were gathered, among which 119 were unique. The set was optimized by reducing the synonyms (such as “utilization” and “usage”), leaving 45 KM activities. These activities may alternatively be viewed as operations executed on knowledge resources (see Table 1).

Step 4 covered the combination of results obtained in steps 2 and 3 with outputs of a parallel research on IT systems classified (by their authors or certification bodies) as supporting knowledge management. The focus of the research was to make an inventory of system functionalities and map them onto the process model in order to see which processes are properly supported by available IT tools.

In the first stage of the study, a list of 1170 knowledge management systems supporting KM was composed, based on leading industry listings (e.g. [4, 7, 9 and 16]) displaying together 937 items, and the web research producing 233 further items.

[13] Valuable research and audit input found in [5, 6, 7, 8, 10 and 11].

[14] See [13] for the specification of the standard and [14] for examples.

Table 1. Unique knowledge management activities in KM definitions and models
(source: self study)

Unique knowledge management activities In KM definitions and models		
- acquisition	- implementing	- reuse
- adding context	- improving	- searching
- analyzing	- increasing adapting	- securing
- archiving	- internalizing	- securing
- capturing	- interpreting	- selecting
- certifying	- learning*	- selling
- classifying	- localizing	- sharing
- coding	- maintaining	- staging
- compressing	- maximizing usage	- storing
- creating	- measuring	- transferring
- distributing	- organizing	- transforming
- externalizing	- personalizing	- updating
- forecasting	- publishing	- using
- fusion	- quality evaluation	- valuation
- identifying	- restoring	- verifying

* In organizational experiences we also identify the term "de-learning", which is related to removal of old practices that are a source of suboptimal efficiency.

The list was optimized via a series of adjustments, related to duplicates (e.g. due to slightly different naming or spelling mistakes in the lists), removal of solutions listed as "supporting KM", but being rather universal (e.g. Enterprise Resource Planning/ERP), removal of solutions that despite the listing could not be found (possible closure of business) or integrating systems that were merged by company acquisitions and integrated under a single name.

After the optimization, the list was reduced to 907 items. Based on a high level study of the functionalities of the systems, an initial classification of 31 functionality groups was proposed. Examples of such groups include: content acquisition, content management, collaboration or meta data management.

In the next step a selection of 10 most often mentioned or discussed IT systems was made as a sample for a detailed functional study, based on system documentation and consultations with system vendors. As a result of working only with the initial research population (10) the number of unique functionalities, on various functional levels, went up from 31 to 120. Since the dimensions of the research were quickly increasing in value, the study was limited to 116 systems that were analyzed on a detailed functional level. The end result of the study produced a functional map with 67 main functional groups (see Table 2) and 245 subgroups in a maximum 3 level hierarchy.

The system study performed in step 4 allowed to significantly extend the understanding of various knowledge management processes that are in use by organizations. Some of the processes became visible from the perspective of particular business domains such as the data protection in the public sector or the constant capture of selected medical information on patient behavioral patterns.

Other processes were clarified or defined, beyond their plain keyword character (e.g. authoring as a process consisting of multimode and multiparty generation of content, where aspects of localization, translation and versioning are taken into account). The resulting process map contains 88 second level processes and 174 third level processes, all organized in a hierarchy linked to the 7 key knowledge management processes.

Table 2. Main functional groups of knowledge management supporting systems
(source: self study)

Main functional groups of knowledge management supporting systems		
- Abstracting Services - Independent Summarization and in Search Functions - Analytical Applications (Business Intelligence, Analytics, Corporate Performance Management, Insight generation) - Archiving (Revision-Proof), including Email Archiving - Author Management - Authoring Tools - Blogging (Blog) - Business Activity Monitoring - Business Process Management (Process Engine, Process Automation) - Case Management - Catalog Management - Collaboration - Resource Sharing - Collaboration - Scheduling (People, resources, calendar) - Collaboration and communication - Competitive Intelligence - Compliance Management - Content Management System - Content Acquisition (Capture, Input Management) - Content Delivery (Distribution, Publishing, Output) - Content Indexing (Categorization, Classification, Tagging) - Content Information Quality	- Content Store (Warehousing and Infrastructure) - Content/Data Integration - Continuous Archiving of Personal Experience (CARPE) - Digital Asset Management - Digital Rights Management - Document Management - Dynamic Document Control - eLearning (Learning Management System) - Email Management - Expert Management (identification, search, ranking, evaluation) - Expert System (Decision Support System) - Forms Management - Graphical Knowledge Modeling - Help Desk Management - Idea Management (Suggestion Box) - Identity Management - Image Management (Imaging) - Information Extraction (Knowledge Elicitation) - Information Rights Management - Knowledge Activity Monitoring - Lifetime Personal Information Management - Metadata Management - Personal Knowledge Management (also Networked)	- Policy management - Portal - Print management - Project Management - Questions and Answers - Real Time Data Feeds (RSS) - Records Management - Reference System - Regulation Change Information - Reporting (Enterprise Reporting, Reports management) - Repurposing (Rendering, Editorial Component) - Retention Policy Services - Rich Media Search - Search and Retrieval (Search Relevance) - Security Assurance - Semantic Web - Taxonomy Management - Terminology Suite - Text Mining and Analytics - Topic Maps - Version Control (also de-duplication) - Web Content Management - Wiki/Wikipedia - Workflow

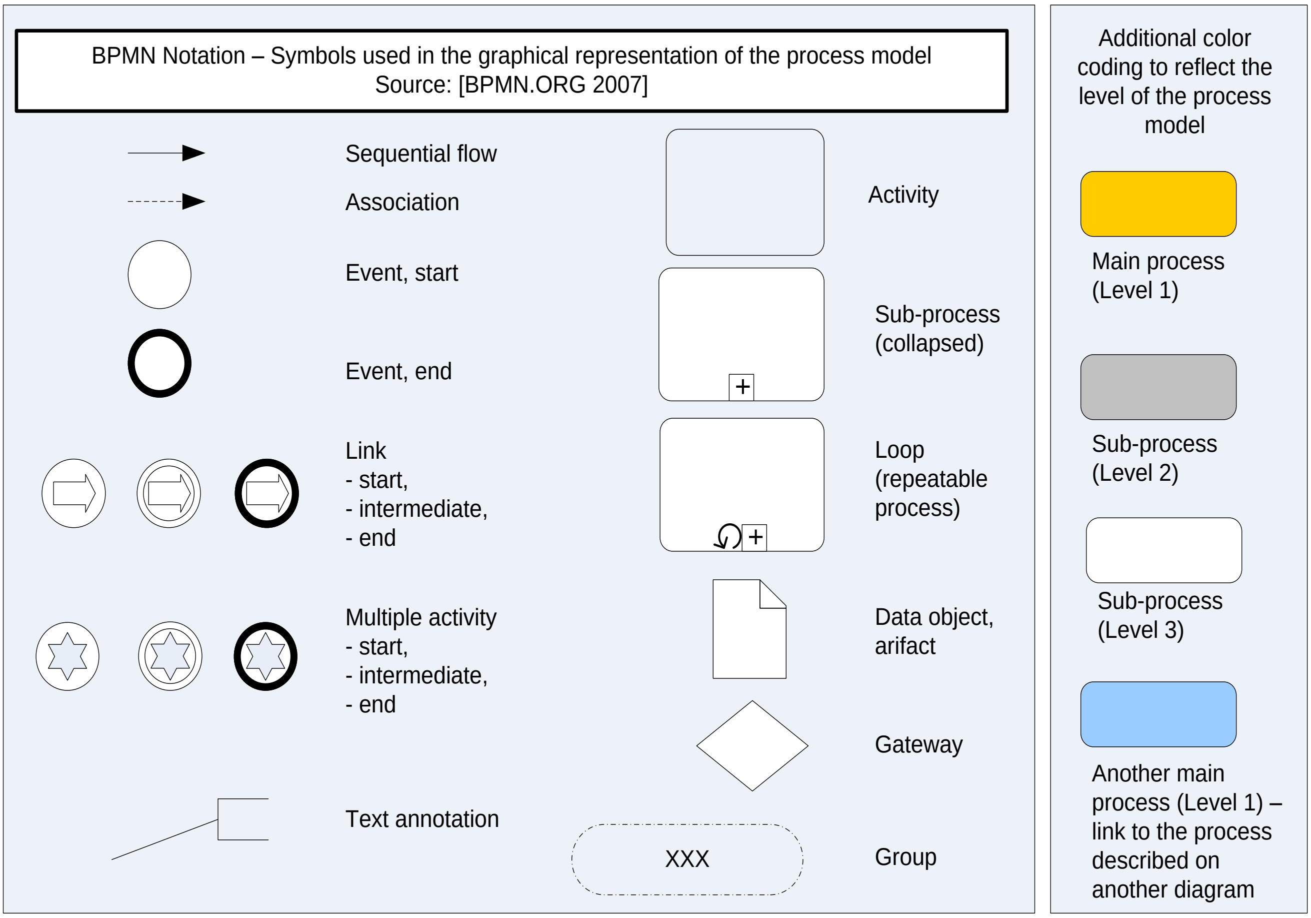

Figure 2. Elements of the BPMN used in KM process modeling
(source: [13])

The structure was compared with a best practice example from a large scale process modeling activity in the area of retail banking[15].

The knowledge management model with a hierarchy of 7-88-174 processes on each of the 3 levels (2%-33%-65% in a percentage view) was similar to the retail banking model showing the structure of 7-47-232 (2%-17%-81%) processes on each level.

Taking into account the fact that the retail banking process hierarchy was proven to successfully support business reengineering activities of several organizations, it was assumed that the proposed hierarchy of KM processes also holds the potential for practical use in the KM process modeling[16].

The research and development conducted in steps 1-4 became a base to develop detailed knowledge management process models, providing a conceptual overview of the entire KM domain. The models were created using the BPMN process documentation standard. Elements of the BPMN used in the diagrams are presented on Fig. 2. A sample detailed map for the process A. Identification (of knowledge or knowledge resources) is presented in Fig. 3.

The process of resource identification is concentrated on specifying a map of knowledge resources available in the organization. In order to best serve this purpose, it is very useful to start with creation of a conceptual framework of what knowledge the organization is dealing with.

[15] The author was one of the main experts developing the retail banking process model, as a part of a large Business Process Reengineering activity run by Accenture for a leading financial group in Europe.

[16] The author was not able to find any research that would address the topic of the desired level of detail in process modeling. The check against the retail banking model was the most easily available way of verifying the usability of the proposed KM process hierarchy.

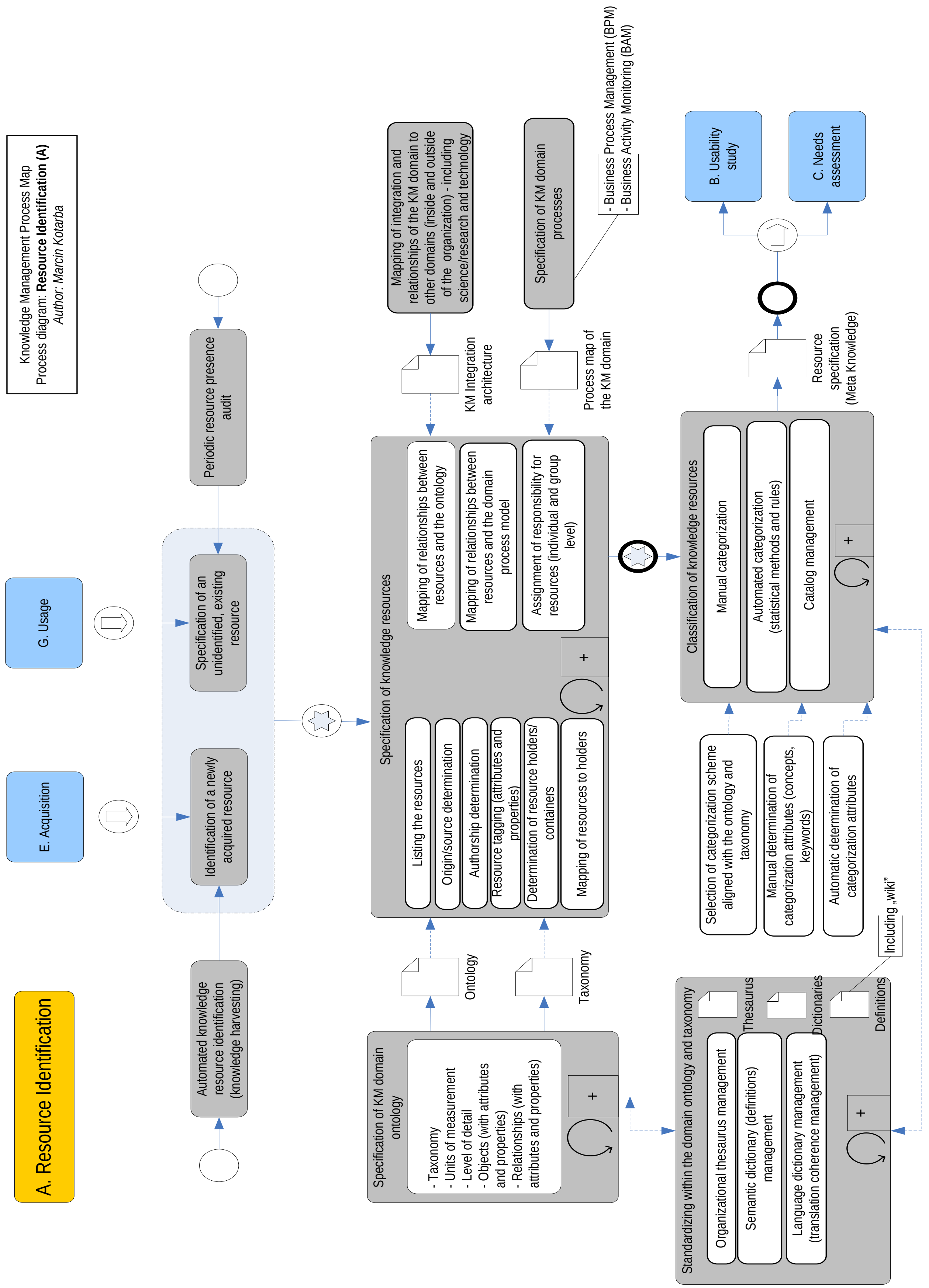

Figure 3. Detailed model of the resource identification (A) key knowledge management process *(source: self study)*

There are three key processes (A.1-A.3) that allow for building such a foundation:

A1 Development of the ontology for the knowledge management domain (linked to a selected business area), covering:

A.1.1 Formulation of the taxonomy

A.1.2 Evaluation of the desired level of detail for the ontology

A.1.3 Specification of objects in the KM domain (including the properties and attributes)

A.1.4 Specification of relationships between objects in the KM domain (including the properties and attributes)

A.1.5 Specification of measurement criteria for objects and relationships

A2 Specification of processes in the knowledge management area

A3 Specification of integration and relationships between the KM domain and other domains (internal or external), including academia and technology development.

The ontology, with its underlying terminology (taxonomy) defines a framework of objects and relationships that exist in various value chains of the KM domain, filtered to a specific level of detail and measures. We can compare it to a base map of a medieval castle with a high-level outline of functions performed by various architectural components and sections, such as the walls for protection, the turrets for counter-attacks, the castle square for day-time market activity, the water cistern, the blacksmith workshop, the winery or the arms storage. The legend on the map leads us through the morphology of the castle, also specifying the proper terms to be used in the description of the structure. The scale reflects the desired level of detail and the measurements allow to compare the size of various elements (e.g. the number of soldiers stationed in the towers). The next step in the understanding of the castle's life is to get a view on what processes are performed in its various quarters.

For example, we may conclude, based on general knowledge, that the blacksmith is responsible for the production of horseshoes and household/farming iron equipment. However, verifying the list of processes executed by our particular blacksmith we may conclude that his profession was also related to the production of weapons.

A comprehensive process study is important to obtain a broad view of organizational activities and is encouraged for every type of organizations. Last but not least we must understand the interactions of the castle with other domains. Internally it could be an interaction between the church and the secular elements of the castle's organization. Externally we can mention the relationships with other castle's, with surrounding villages or even with the capital city or the site of a regional ruler.

This picturesque example shows us the type of understanding of a given KM domain which is a necessary framework for successfully conducting KM activities. Without this insight into the details, it is difficult to properly conduct further KM activities.

The specification of knowledge resources is conducted with reference to the KM domain conceptual framework and covers three main processes (A8-A10):

A8 Specification of knowledge resources (location)

A.8.1 Listing resources, creating an organized and dynamic directory

A.8.2 Origin determination (indication of sources)

A.8.3 Authorship determination (legal purposes, authorization)

A.8.4 Resource tagging (attributes and properties)

A.8.5 Determination of resource holders (containers)

A.8.6 Mapping of resources to resource holders

A.8.7 Assignment of responsibility for resources (on the individual and group level)

A.8.8 Mapping of relationships between resources and the ontology

A.8.9 Mapping of relationships between resources and the processes

A9 Classification of knowledge resources

A.9.1 Selection of categorization scheme aligned with the ontology and taxonomy

A.9.2 Manual determination of categorization attributes (concepts, keywords)

A.9.3 Automated determination of categorization attributes

A.9.4 Manual categorization (operator driven)

A.9.5 Automated categorization (statistical methods, rules)

A.9.6 Catalog management

A10 Standardizing within the domain ontology and taxonomy

A.10.1 Organizational thesaurus management

A.10.2 Semantic dictionary (definitions) management

A.10.3 Language dictionary management (for standardized translations).

The resulting directory provides a broad view on the knowledge resources existing within the organization, together with their clear definition and a set of attributes that can be used for search and management purposes. The research performed by the author shows that the most important knowledge resources are people and organizational artifacts. Knowledge specification is subject to numerous challenges.

When interacting with human resources, we face the issue of tacit knowledge that is difficult to capture and structure. Artifacts on the other hand are explicit, but due to their volumes and complexity we still deal with the issues of unstructured and highly uncontrolled content. However, in both cases the process approach to knowledge specification supports a systematic coverage of the knowledge resources management.

The level of detail as well as the frequency and intensity of resource identification depend on the nature of the organization and its market surrounding. For highly dynamic and complex organizations it may be necessary to run resource identification as a continuous process, while for others it may be sufficient to conduct it as a periodic inventory. Regardless of the frequency, identification needs to be tightly linked to the incoming processes of knowledge acquisition (E) and knowledge usage (G) as they are the foundation for the registration and discovery of new knowledge resources. Four processes are proposed for these activities:

A4 Identification of a newly acquired resource

A5 Specification of an unidentified, existing resource

A6 Periodic resource presence audit

A7 Automated knowledge resource identification (knowledge harvesting).

With the conceptual framework and the knowledge resource directory, the resource identification process (A) can be interfaced with the usability study (B) and needs assessment (C). In the usability study, the resources are verified against the strategy, which results in taking a variety of decisions: keeping and developing the resources, keeping the resources without further investment ("hibernation"), disposing of the assets via sales or simply discontinuing the use of an asset. This process is very important from the cost point of view. By knowing "what" organizations possess and knowing how useful these possessions are, it is possible to better manage the budgets related to generation and maintenance of knowledge resources. A similar conclusion is applicable to the link with needs assessment (C). The better we know what we have, the lower the chance of "re-inventing the wheel" and repurchasing of resources. What is of equal importance is the ability to evaluate whether the resources held are meeting the desired quality criteria. Practical experiences show that it is common to assume that an organization has a required knowledge resource, while in reality this resource is either outdated or highly inaccessible. Increasing the usage and quality of knowledge resources is being pointed out as one of the top expected benefits of knowledge management[17]. It is therefore necessary to implement and continuously improve the processes of resource identification.

4 Working with the Knowledge Management Process Model

In chapters 1 and 2 the overall concept of the process based approach to knowledge management was presented, together with a more detailed pass through the selected main process of resource identification (A). Since the author claims there is a limited availability of practical implementation guidelines, methods and tools[18] in knowledge management, it is necessary to see how the process model can be used by organizations to support their KM goals.

The process model of KM is a proposal of an open reference model that can be used for both research, implementation and improvements of KM practices. The model offers a comprehensive and detailed specification of an inter-related KM process hierarchy. This hierarchy can be a base for analyzing the organizational "as-is" situation and for defining the desired "to-be" state.

[17] The author conducted a research of 26 description of KM benefits (322 instances of various benefits) and 21% of them were related to the increase of the level of use and the quality of knowledge resources.

[18] Some of the most widely discussed tools include: IPscore [11] and the Intangible Assets Monitor/IAM [17]. These tools however are mostly applicable to valuation and monitoring of intangible assets of organizations.

Following this logic, the author developed a method and a tool for auditing and planning KM improvement activities. The tool, code named KMBoost, was built as an MS Excel spreadsheet containing the full list of KM Processes (269 items), together with a scoring mechanism, for measuring current and target performance of the organizational knowledge management.

The scoring is located on each process level (1-3). It covers a declarative statement whether a given process exists in the organization and the perception of weight that the process has for the organization.

The score is calculated as follows:

$$\text{Score} = \sum_{p=1}^{269} \text{weight}_p * \text{presence}_p \qquad (1)$$

Where for every process (p) from the list of 269 KM processes, the user declares a factor of presence = {0; 1} and its importance weight = {0; 0,25; 0,5; 0,75; 1}.

The tool is pre-populated with values of weights that were compiled by the author based on research and experience. The difference between the total as-is and the to-be score reflects the planned level of improving the knowledge management practices of the organization.

This feature is one of the key goals of KMBoost as a tool to allow for better understanding of knowledge management and increasing its performance.

The KMBoost tool contains a number of additional features, such as the evaluation of organizational artifacts (drivers of complexity), mapping between the processes and the IT solutions supporting KM, descriptions of IT functionality groups, descriptions of processes and graphical representation of scores (on the radar screen diagrams), presenting the as-is, to-be and benchmark scores.

All of the features of KMBoost are provided in the open, customizable format, which allows to be modified, exported or enhanced by importing lists and other features. Although the tool is linked to a proposed method of application (from as-is to the to-be in the continuous improvement cycles), there are no limitations with respect to other uses of the tool's content, especially addressing the questions:

- do we understand the scope/subject matter of knowledge management?
- do we manage knowledge in a conscious and organized manner?
- how advanced are we in managing knowledge?
- what KM practices should be implemented or discontinued?
- what should be improved in the present/active KM practices?
- how to plan KM improvements?

The underlying detailed KM process model (269 items) remains the core of the concept. Various studies can be conducted based on this model, while the model itself can also be subject to further development, both horizontally (new processes) or vertically (higher levels of detail). Users have the choice of following this expert weight scheme or introducing any changes specific to their organizations.

The factor of presence is recorded in the tool in two versions:

- describing the current ("as-is") situation,
- and the desired, target ("to-be") situation.

This approach is in-line with the business process reengineering principles where improvement of organizational activity is reached by a clear outline of the target process architecture and performance.

As a result, two total scores ("as-is" and "to-be") are calculated and expressed in the widely used RAG[19] standard. The red as-is status (coverage of processes below 60% of the total process directory) is interpreted as a necessity to immediately take action to improve the KM practices of the organization, since most likely several key processes are missing. The green as-is status is achieved above 80% of presence of the total process directory and can be viewed as reflecting high commitment of the organization to the KM agenda.

The amber status (between 60 and 80% of process presence) is interpreted as the area of threats (potential fall to the red zone) or opportunities (movement up to the green zone). In every RAG group additional scores are determined, with a total of 8 groups between the worst score (F) and the best score (A), following some typical academic scoring guidelines.

[19] RAG (Red, Amber, Green) is a system of "traffic lights" aimed at reflecting an overall status of a given initiative.

Table 3. Strengths and weaknesses of the process KM model and tools
(source: self study)

	KM Process Model	KM Process Tool – KMBoost
Strengths	- high level of detail in the process model (broad view of KM in organizations) - open nature of the model, allowing its further development or customization - usage of a practical (commonly used) process description language (BPMN)	- complete reflection of the process model (3 levels) and synchronization with the theoretical models - simple, but efficient scoring - usage of an open application environment, user friendly and customizable - link between KM processes and functionalities of IT systems supporting KM
Weaknesses	- high level of detail to be absorbed, especially if the time for workshops is limited. Requires a lot of effort to manage - lack of extensive description for each knowledge management process (reader must be well acquainted with KM before starting with the process model)	- the system of self-assigned weights too complicated, therefore a tendency exists to use the expert weights - lack of comparison with other organizations. Availability of benchmarks would greatly increase the value of the tool - it is difficult to work with the tool and methods without additional expert instruction. Potentially 1 additional session should be added prior to the workshops, just to clarify the model, methods and tools

5 Closing Remarks

The process model and the KMBoost tools were successfully verified by the author in several organizations varying in size and types of business (finance, banking, production, trade, scientific research laboratory). The research workshops with organizations included a questionnaire on the strong and weak points of the model and the KMBoost tools, as perceived by the users. The summary of key feedback can be found in Table 3. The positive evaluation of the proposed knowledge management process model, with the accompanying methods and tools provides strong encouragement to continue the study and development of this approach. Also, all weaknesses that were pointed out can be improved to deliver a higher quality model and tools (no blocking or critical weaknesses). Obviously the proposed process approach is not a panacea for all knowledge management issues. It is however a way to increase the understanding of knowledge management, its particular architecture and modus operandi in various organizations. The process approach defines a detailed view on "what" is knowledge management. The methods and tools associated with the usage of the process model allow to specify the "how" of knowledge management. This "how" is especially important for organizations that want to implement or improve knowledge management. Are there any organizations out there that would deny the necessity to do so?

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HOW TO PERFORM DISCOUNTED CASH FLOW VALUATION?

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***Abstract*:** Within the last few decades the quickly accelerating globalization processes contributed to rapid increase in the value of the global capital markets, and mergers and acquisitions transactions. This implicated the rising importance of methodologies that enable investors to efficiently value the companies. The aim of this elaboration is to present practical approach towards the discounted cash flow company valuation method, considered one of the most effective but simultaneously one of the most sophisticated among all. The article comprises purely theoretical as well as practical knowledge, based on the author's broad professional experiences.

Key words: valuation, discounted cash flow, free cash flows to firm, free cash flows to equity, residual value, discount rate, beta, market risk premium.

1 Introduction

In theory, the fair market value of a company can be assessed only in a real transaction, at which the shares change hands between a willing buyer and a willing seller. In such transaction the buyer is not under any compulsion to buy, the seller is not under any compulsion to sell and both parties have reasonable knowledge of all relevant facts.

In practice there are few generally accepted methodology of company valuation which often are used for different purposes. The Fig. 1 presents the most often used methodology.

The three principal techniques to value a business that are commonly used include:

- multiples approaches - comparable companies approach (CCA) and comparable transactions approach (CTA),
- discounted cash flow approach (DCF),
- adjusted net book value approach (ANBV) [12].

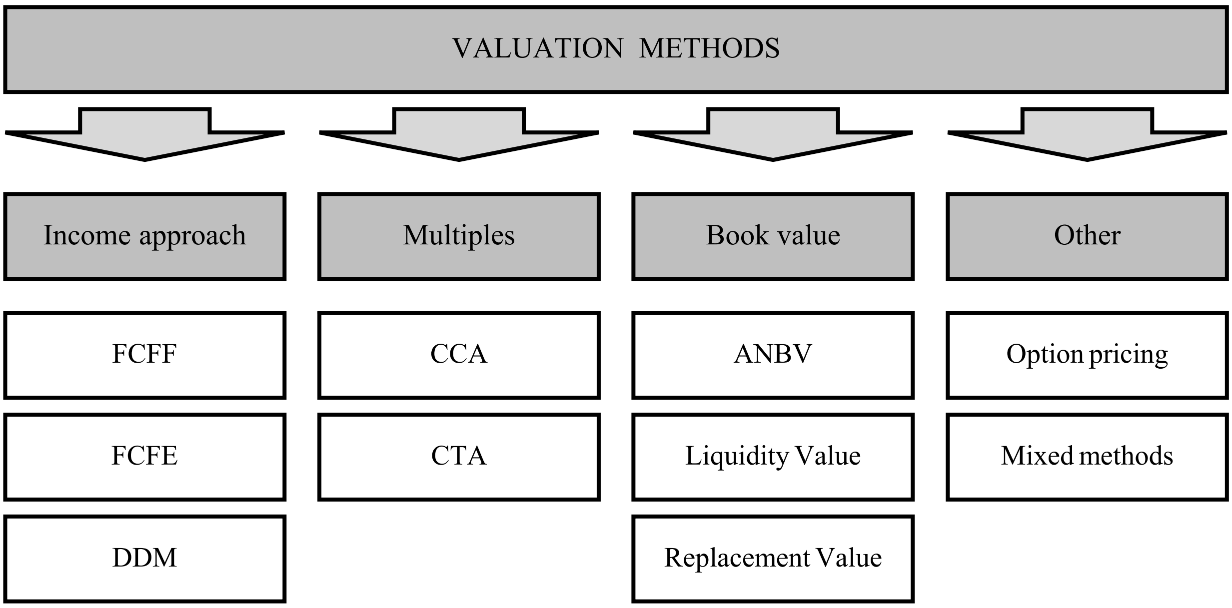

Figure 1. Company valuation methods
(source: self study)

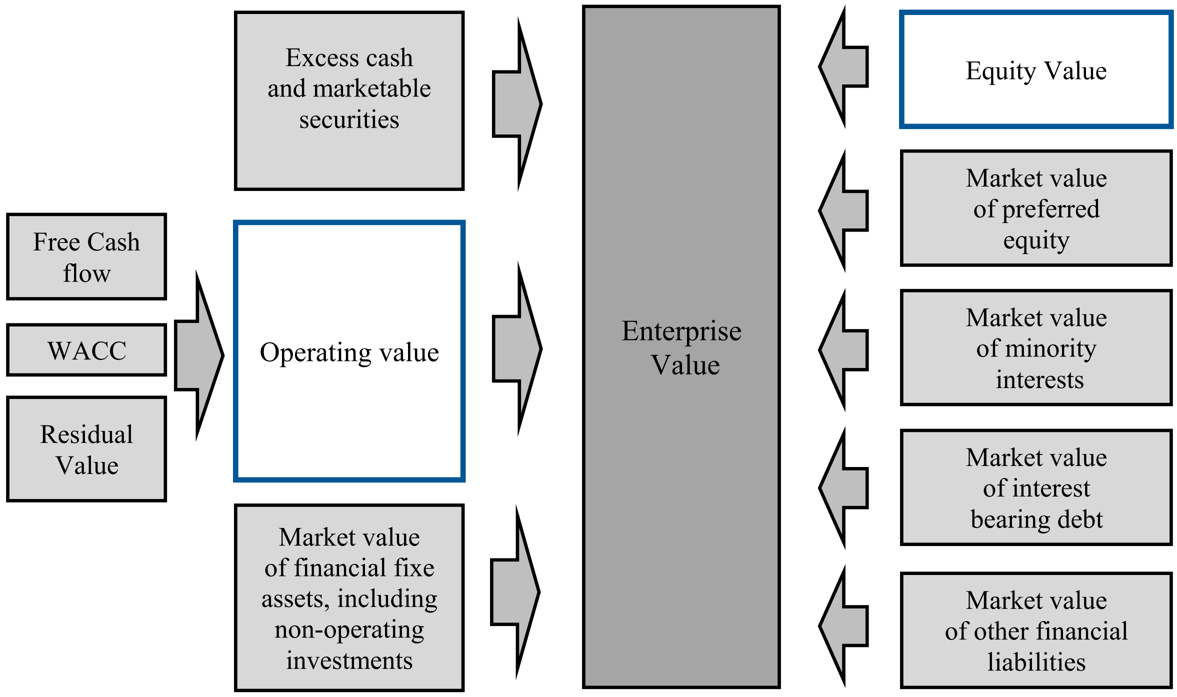

Figure 2. Graphical summary of DCF approach
(source: self study)

The purpose of this article is to elaborate how to prepare DCF valuation in most effective way. DCF valuation presents future growth of the company and additionally discounts the risk of the business applying specific discount rate that reflects each industry risk.

2 Discounted Cash Flow Methodology

Discounted Cash Flow methodology assumes that the present range of values of the company as of the valuation date is equal to the present value of future cash flows to the company shareholders. Due to the limitation of the period of the financial projections the value of the company is a sum of two factors:

- the present value of cash flows (sum of the present value of dividends that the company may afford to pay out to shareholders and/or additional capital injections made by the shareholders),
- residual value of the company, which is the discounted value of the company resulting from cash flows generated by the company after the projections period.

The cash flows are derived from financial projections compiled in accordance with assumptions. Depending on whether Free Cash Flow to Firm (FCFF) or Free Cash Flow to Equity (FCFE) calculation is used in DCF valuation the cost of capital or the cost of equity of a valued company, shall be used as discount rate [10].

The Fig. 2 presents the graphical summary of DCF approach. The following three factors: free cash flows, discount rate and residual value are used in assessing the value of the operating assets (cash-flow generating assets) of the company. This value combined with the value of non operating assets (non cash-flow generating assets - primarily divided into two group: excess cash, marketable securities and other non operating assets) constitutes the enterprise value of a company.

The major steps in valuation using DCF approach are summarized in Fig. 3.

3 Financial Projections - assumptions

Financial projections for the valued entity shall be based on the assumed values of key drivers – independent factors that have material impact on the company financial performance. The thorough analyses of the variables affecting financial performance and the right selection of the key drivers are the necessary elements of the appropriate DCF approach. It also allows to perform sensitivity analysis in a simple and reliable way.

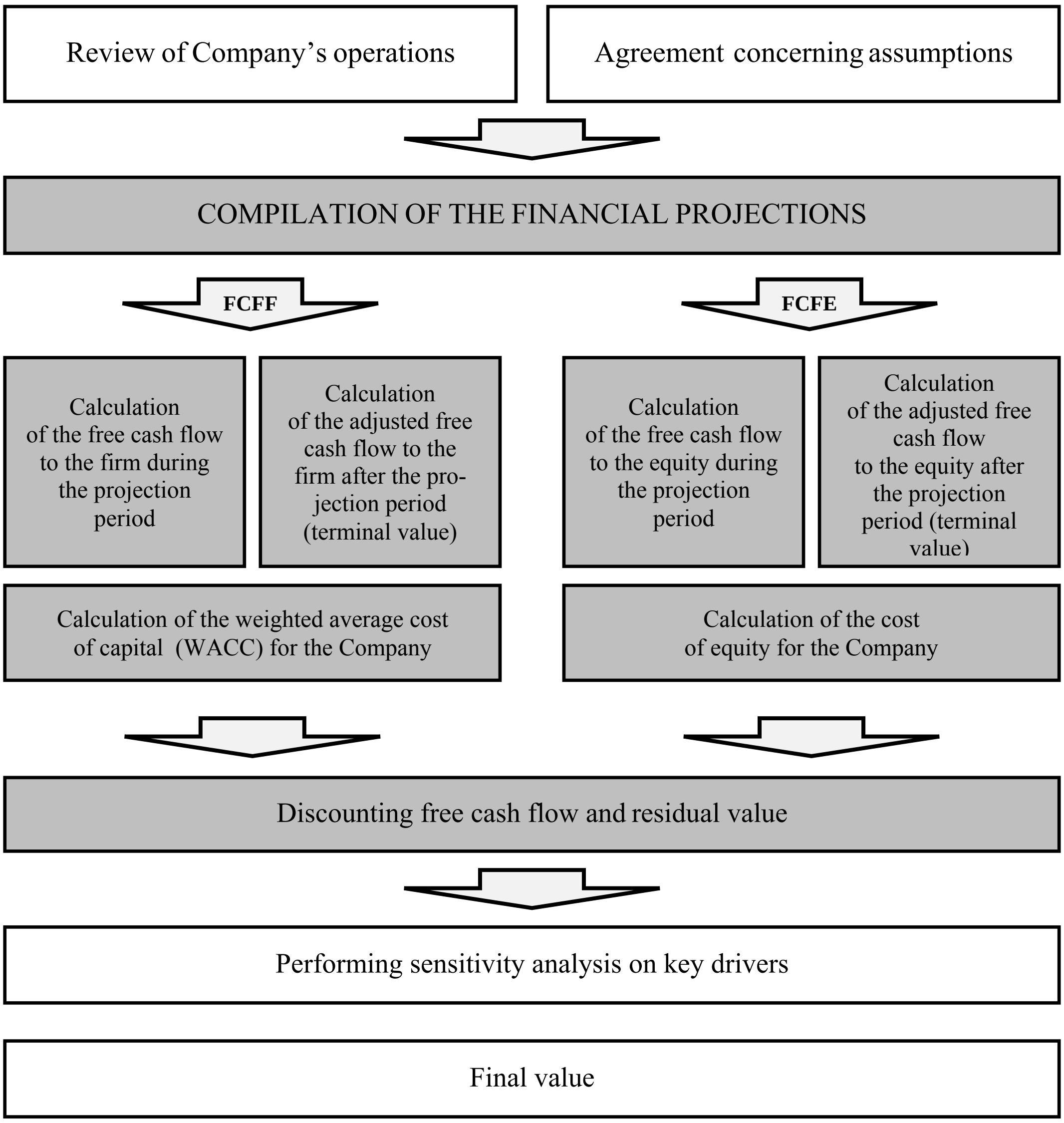

Figure 3. The major steps in valuations using DCF approach
(source: self study)

It shall be underlined that not the more key drivers are identified, the better the valuation would be. Only those variables that are independent from each other and carry significant explanatory power for the financial performance of the company shall be assessed as key drivers. A rough estimation states that the number of key drivers shall not exceed ten variables (assuming standard complexity of the financial model).

An exemplary selection of key drivers is presented below:

- sales volume increases/decrease (with respect to group of products and distribution channels),
- real price increase/decrease (with respect to group of products and distribution channels),
- profitability margins (with respect to group of products and distribution channels),
- number of clients (with respect to group of clients),
- average revenues per client (with respect to group of clients),
- capital expenditures.

It must be however remembered that key drivers vary within different industries and often include business specific factors.

The financial projections for the valued company can be compiled using three categories of information:

- information concerning macroeconomic factors,
- information concerning the industry in which a business operates,
- information specific to the business.

Table 1. List of sources for the basis of DCF approach
(source: self study)

Macroeconomic factors	Industry factors	Business factors
– External databases and services - World Market Research Centre - EIU - Eurostat - SL Bloomberg – Commercial bank reports e.g. - Citibank - BPH - Millenium	– External databases and services - One Source - Factiva - Thompson Research - SL Bloomberg - Standard & Poor – Industry reports (both external and internal)	– Financial statements – Management reports – Business analysis – Information from management

Table 2. The summary of the benchmark treatment to the calculation of main captions in the financial projections
(source: self study)

FORECASTING FINANCIAL STATEMENTS	
Profit & loss account	
Revenues growth	- % growth - price % growth - production output - production output % growth - market share % growth
Operating costs growth	- % of revenues - mark-up - sales margin - production unit cost % growth - labour cost salary/employment % growth
Depreciation and amortisation	- depreciation rate as % of gross fixed assets
Balance sheet	
Inventory turnover	- turnover in days of selected operating costs - turnover in days of revenues
Receivables turnover	- turnover in days of revenues
Operating cash turnover	- % of revenues - turnover in days of revenues
Payables turnover	- turnover in days of selected operating costs - turnover in days of total costs
CAPEX	- % of gross fixed assets - % of depreciation and amortisation

In general information on the macroeconomic factors and industry specific factors might be obtained from publicly available sources whereas the information on the factors specific to the valued entity shall be primarily provided by the management of the company.

The list of the sources which might constitute the basis for DCF approach valuation is presented in Table 1.

Set of assumptions shall provide both the information on the values of key parameters of the model and on the methodology of calculation of the certain captions in the financial projections.

The summary of the benchmark treatment to the calculation of main captions in the financial projections is presented in Table 2.

The duration of the financial projections shall be heavily dependent on the forecasted performance of the valued entity. The general rule is that the duration of financial projections shall be at least equal to the period in which the company is supposed to reach the stable growth in perpetuity. The financial projections shall cover the period long enough to estimate a normalised or mature level of cash flows prior to deriving to terminal value. The residual value shall be calculated no earlier than when steady state of the business' operations arrives – this implies that all the value drivers in the financial projections would remain constant [12, 4].

In spite of the fact that while projections become less reliable further out, it still may be necessary to go out up to 10 years or more in order to reach normalised levels. Furthermore, if the valued company is expected to have a competitive advantage for a certain period, the financial projections duration should be of sufficient length to capture the entire period of this competitive advantage.

Summary of the factors that are useful in determining the duration of financial projections for the purposes of DCF valuation is presented below:

- the length of high growth or transition growth period,
- industry cycle and competitive structure (operating margins),
- economic cycle,
- knowledge of significant events,
- useful life of assets (e.g. coal, oil, etc.),
- comfort of the person responsible for the assumptions,
- length of any competitive advantage.

It is important to remember that usually longer financial projections period allows reducing the impact of the residual value on the valuation results. It is important argument for extending the period of financial projections – the vogue estimate is that residual value shall constitute no more than 50,0% of the company value. In other cases the valuation result becomes very sensitive for the changes in projected cash flow in the last year of financial projections, which is the base to calculate the residual value [2].

4 Structure of the financial model

The structure of the financial model shall primarily consist of three separate modules (see Fig. 4). The content of each of these modules might very case by case but in general shall follow the following characteristic:

- Input module
  - macroeconomic assumptions
    - market specific factors (market growth, saturation, etc.),
    - GDP and inflation,
    - interest rates (T-Bills, WIBOR, LIBOR, deposit rate, etc.),
  - operational assumptions
    - sales (volume increases, real price increases, etc.),
    - costs (margins, unit costs of materials, etc.)
    - capital expenditures,
    - working capital (turnover of receivables, payables, inventory and operating cash),
    - other assumptions (dividend payout ratio, etc.),
  - KVD spreadsheet with sensitivity analysis and key parameters analysis,
  - control cells that indicate the correctness of both input data and calculation process.

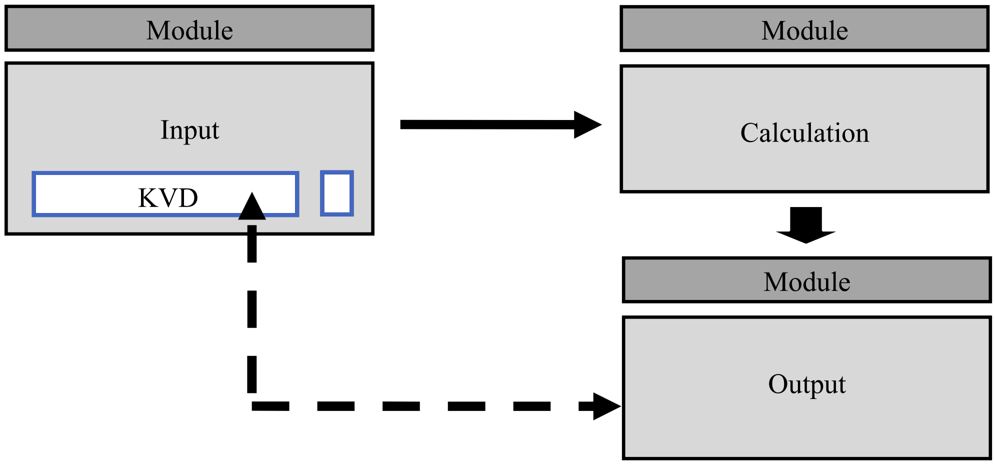

Figure 4. The structure of financial model
(source: self study)

- Calculation module
  - calculating formulas and performing conversion of input/output variables:
    - calculation of sales revenues (division of sales in respect to products and distribution channels),
    - calculation of cost by nature (materials & energy, depreciation, external services, payroll, etc.),
  - should not include sensitivity analysis and statistical tests,
  - should not include input cells (input data).
- Output module
  - presentation of the final results on the aggregated level:
    - profit and loss account,
    - balance sheet,
    - cash flow statement,
  - presentation of additional measures of financial performance:
    - sales and operating costs analytics,
    - ratio analysis.

While compiling financial projections it is necessary to follow a hierarchical model of data. The flow of information implemented within the financial model shall follow the Fig. 5.

Linking the analytical-level spreadsheets directly to output-level spreadsheets shall be avoided. The information flow shall be always gradual from the most detailed data to the most aggregated levels (e.g. profit and loss account, balance sheet and cash flow statement).

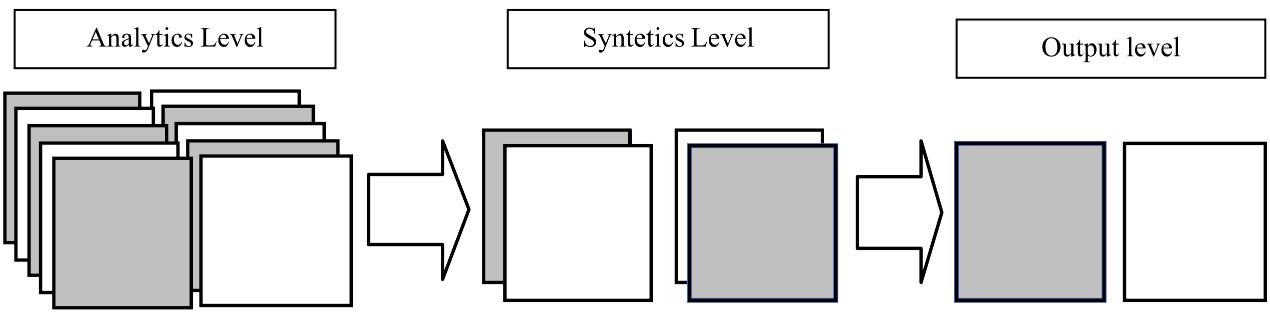

Figure 5. The flow of information implemented within the financial model
(source: self study)

EBIT	Earnings Before Interest and Taxes – the figure derived from Profit and Loss account (adjusted for extraordinary items)
+	
Depreciation and amortisation	Depreciation of all tangible and intangible assets (separate treatment of goodwill amortization might be considered) - the figure derived from P&L
+	
Corporate Income Tax paid (-)	The figure derived from Profit and Loss account adjusted for Balance Sheet captions – deferred tax asset/liability unless additional CIT calculation spreadsheet is available
=	
GROSS CASH-FLOWS	
+	
Changes in Working Capital	Usually split into following categories: changes in operating cash, receivables, payables and inventory - the figures derived from Balance Sheet
+	
Changes in other assets and liabilities	Usually split into following categories: prepayments, financial assets (excluding cash), reserves and accruals excluding changes in deferred tax asset/liabilities - the figures derived from Balance Sheet
=	
OPERATING CASH-FLOWS	
+	
Capital Expenditures (-)	This caption might be split into two categories: replacement capital expenditures and expansion capital expenditures - the figures derived from Fixed Assets summary spreadsheet
+	
CASH-FLOWS BEFORE FINANCING	
+	
Change in Indebtedness	The difference between the debt issues and debt repayments - the figures derived from Balance Sheet
+	
Net Interest	The difference between the interest revenue and interest expense the figure derived from Profit and Loss account
=	
FREE CASH-FLOWS TO EQUITY	

Figure 6. Methodology of FCFE calculation
(source: self study)

Depending of the complexity of the model the level of analytics and synthetics might be limited to one spreadsheet (including e.g. calculation of sales revenue for product A and B on the bottom of the spreadsheet - analytical level spreadsheet and summary of these calculations on the top of the spreadsheet - synthetic level).

The value of the company is determined by the capacity of its assets to generate cash. Therefore, after compilation of financial projections, it is necessary to estimate free cash flows to shareholders/firm for every year of the financial projection period.

When valuing the firm (enterprise value) FCFF approach shall be used and free cash flows to firm (prior to debt payments) shall be estimated. On contrary, when valuing equity of the company, FCFE shall be used and free cash flows to shareholders shall be estimated [3, 4].

5 FCFE approach

Free cash flows to equity are the cash flows leftover after meeting all financial obligations, including debt payments and after covering capital expenditures and working capital needs. A methodology of FCFE calculation is presented in Fig. 6.

Free Cash - Flows to Equity

+

Dividends paid

-

Increases in shareholder's capital

=

CHANGE IN EXCESS CASH

Figure 7. Formula to estimate change in excess cash
(source: self study)

In order to estimate the value of equity of the company it is necessary to calculate first annual changes in the excess cash within the financial projections period.

These changes might be simply estimated by subtracting the increases of shareholder's capital and adding back the dividends paid out in every year of the financial projections period. It shall be remembered, that the dividends proposed for one year (redistribution of profit for the year N) are usually paid out to shareholders during the following year (N+1) (see Fig. 7).

It is important to estimate and discount cash flows assuming that cash flows occur evenly throughout the years of financial projections. All the cash flows within projection period are assumed to fall on 30th June and are discounted based on half year discount rate. For example, a cash flow between period 2 and 3 should be discounted by $(1 + \text{Discount rate } [\%])^{2,5}$.

6 FCFF approach

Free cash flows to firm are the cash flows that are available to all providers of the company's capital, both creditors and shareholders, after covering capital expenditures and working capital needs. Therefore FCFF are projected on an unlevered basis, before subtracting interest expenses. In other words, FCFF reflect the cash generated by company's all assets, independently of how the assets are financed (capital structure of the company).

A methodology of FCFE calculation used by EYCF employees is presented in Fig. 8.

The tax paid used in calculation of FCFF shall be adjusted for the effect of tax shield on the financial expenses and financial revenues.

EBIT

+

Depreciation and amortisation

+

Adjusted (for interest) Income Tax paid

=

GROSS CASH-FLOWS

+

Changes in Working Capital

+

Changes in other assets and liabilities

=

OPERATING CASH - FLOWS

+

Capital Expenditures

=

FREE CASH – FLOWS TO FIRM

Figure 8. Methodology of FCFE calculation used by EYCF employees
(source: self study)

Income Tax paid

+

Tax shield on financial expenses

+

Tax shield on financial revenues

=

Adjusted (for interest) Income Tax paid

Figure 9. Tax paid used in calculation of FCFF
(source: self study)

These adjustments shall incorporate the effective tax rate (reflecting whether EBIT is negative or positive) instead of the nominal tax rate. Therefore the following formulas might be applied (see Fig. 9)

It is important to estimate and discount cash flows assuming that cash flows occur evenly throughout the years of financial projections. All cash flows within projection period are assumed to fall on 30th June and are discounted based on half year discount rate, as explained in previous chapter [9].

7 Residual value

Residual value of the company is the discounted value of cash flows generated by the company after the projections period. Depending on whether FCFE or FCFF is used, normalised cash flow to shareholders or to both shareholders and bondholders (creditors) shall be applied.

The two approaches to estimate residual value are:

- perpetuity value (based on Gordon Growth Perpetuity Model),
- exit multiple.

As terminal value constitutes the material part of majority of the valuations it is necessary to provide additional control procedures upon correctness of its estimations. Therefore it is recommended to use both perpetuity and exit multiple approaches as a test of reliability of the terminal value results. It might be useful to calculate the EBIT, EBITDA and BV multiples implied by a perpetuity growth terminal value and vice versa.

A stable growth perpetuity model assumes that the cash-flows beyond the residual value will grow at a constant rate in perpetuity. If long term-growth is assumed at level of nil it implicitly assumes a company earns its cost of equity (capital) on all new investments into perpetuity. As such, the level of investment growth is irrelevant because such growth does not affect the value. The formulas for a terminal value assuming stable growth in perpetuity are as in Fig 10.

Residual value calculation

Residual value

$$= \frac{\text{FCFE (year N)} \;*\; (1 + \text{Long term growth})}{\text{CAPM (year N)} \;-\; \text{Long term growth}}$$

$$= \frac{\text{FCFE (year N)} \;*\; (1 + \text{Long term growth})}{\text{WACC (year N)} \;-\; \text{Long term growth}}$$

Figure 10. The formulas for a terminal value assuming stable growth in perpetuity
(source: self study

On that chart N stands for the final year of the financial projections period, and g stands for the nominal long-term growth rate expected in perpetuity. It is essential to ensure that the terminal value is calculated based on consistent basis (nominator and denominator):

- CAPM – FCFE approach and WACC – FCFF approach,
- real long-term growth – valuation in real prices and nominal long-term growth – valuation in current prices.

Long-term growth rate is one of the most important parameters of the valuation using DCF approach. It affects both sides (nominator and denominator) of the terminal value equation. Therefore even small changes in the long-term growth rate have significant compounded effect on the value of the company. Residual value estimation based on exit multiple is treated as an alternative approach. In this approach the value of the firm after the period of financial projections is estimated be applying an industry multiples (the multiples are usually estimated based on comparable quoted companies analyses) to the relevant financial data of the valued entity.

The three main aspects shall be reviewed for the consistency of exit multiple approach.

- Adjusted (normalised) multiples values as of the last year of financial projections

When selecting a multiple, a normalised level should be used. An industry multiple, adjusted to take into account of cyclical variations and the country growth level at the terminal year, shall be applied.

Moreover the multiples shall reflect the relative valuation that would be performed taken into consideration of economy and industry growth stage as of the last year of the financial projections. Theoretically it might be considered to apply the current multiples calculated for Western European countries while estimating the terminal value for the Polish company (assuming the financial projection period of c.a. 10 years) in order to adjust for the differences in current and future stage of Poland's economy development. However, in valuation practise, mainly due to the limitation of date and lack of transparent criteria, it is acceptable to apply historical multiples.

- Financial results as of the last year of financial projections

While estimating terminal value, it is necessary to apply the financial results recorded by the company in the last year of final projections. In neither case the historical results (actually recorded) of the company might be used and the necessary discount rate then provided.

The logical explanation is that the difference between the value of the company estimated using multiples approaches and the value of the company using DCF approach, with residual value computation based on exit multiple, shall be comprised by the variations of forecasted company's cash flows against forecasted industry average cash flows (implicitly used in multiples valuation approaches)

- Adjusted (normalised) financial results

While estimating terminal value the adjusted (normalised) financial results as of the last year of financial projections shall be used. In other words the financial results constituting the base for terminal value estimation shall be adjusted for unusual and non-recurring items and valuation-specific items. The former might be performed by either excluding non-recurring items or applying average figures (in case of cyclical businesses average EBIT, EBITDA over the course of a cycle might be used). In case of cash-flow derived multiples it is appropriate to use normalised cash flows. In case of using book value multiples additional adjustments are necessary if FCFF or FCFE valuation approach is used.A terminal value is typically determined as a multiple of EBIT, EBITDA or BV (mind the constraints mentioned below). The applicability of the multiples in estimating terminal value in respect to different DCF approaches is presented in Table 3.

Resuming it is recommended to use EBIT or EBITDA multiples in FCFF and FCFE approaches. BV multiples might only be used in case the book value as of the last year of the financial projection period is adjusted (decreased) with all the excess cash being distributed among the shareholders [5].

8 Discount rate

The discount rate is a function of the risk inherent in any business and industry, the degree of uncertainty regarding the projected cash flows, and the assumed capital structure. In general, discount rates vary across different businesses and industries. The greater the uncertainty about the projected cash flows, the higher the appropriate discount rate and the lower the current value of the cash flows.

Table 3. The applicability of the multiples in estimating terminal value in respect to different DCF approaches *(source: self study)*

Exit multiple	Free Cash Flow to Equity	Free Cash Flow to Firm	Dividend Discount Valuation
EBIT	- use normalised cash flows	- use normalised cash flows	- use normalised cash flows
EBITDA	- use normalised cash flows (in particular implicit assumption that depreciation and amortisation equals capital expenditures)	- use normalised cash flows (in particular implicit assumption that depreciation and amortisation equals capital expenditures)	- use normalised cash flows (in particular implicit assumption that depreciation and amortisation equals capital expenditures)
Book Value	- book value shall be adjusted (decreased) with all the excess cash being distributed among the shareholders during the period of financial projections	- book value shall be adjusted (decreased) with all the excess cash being distributed among the shareholders during the period of financial projections	- no adjustments

The consistent approach to valuation requires application of cost of equity while discounting cash flows attributable to shareholders (FCFE) and weighted average cost of capital while discounting cash flows attributable to both shareholders and bondholders (FCFF). The exception occurs when the valued entity bears the very high financial leverage (c.a. above 90%) during the whole financial projections period. In such case calculation of discount rate for FCFF using CAPM is appropriate (in such case debt holders carry the risk similar to the one carried by shareholders).

While performing valuation, the discount rate shall be equal to cost of equity of the company. It assumes to estimate cost of equity using Capital Assets Pricing Model ("CAPM"). The discount rate is estimated using the following formula:

$$C_E = R_F + \beta \times R_P \quad (1)$$

where:

C_E - cost of equity,

R_F - risk-free rate,

R_P - market risk premium being average rate of return above risk-free rate required by shareholders over long time horizon,

β - levered beta, a measure of systematic risk calculated for the projected Debt/Equity ratio for the company.

CAPM assumes that the risk of a given equity to an investor is composed of diversifiable and non diversifiable risk. The former is risk which can be avoided by an investor by holding the given equity in a portfolio with other equities. The effect of diversification is that the diversifiable risks of various equities can offset each other. The risk that remains after the rest has been diversified away is non diversifiable or systematic risk.

Systematic risk cannot be avoided by investors. Investors demand a return for such risk because it cannot be avoided through diversification. Thus, investors demand a return for the systematic risk associated with a stock (as measured by its variability compared to the market) over the return demanded on a risk-free investment. Beta measures the correlation between the volatility of a specific stock and the volatility of the overall market. As a measure of a company's or portfolio's systematic risk, is used as a multiplier to arrive at the premium over the risk-free rate of an investment.

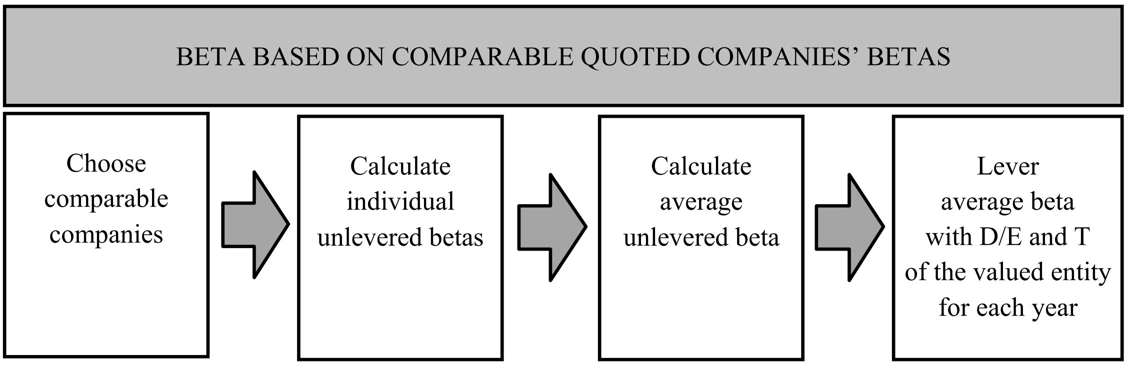

Figure 11. The steps that shall be performed in order to estimate beta for the valued entity (based on comparable quoted companies)
(source: self study)

In theory, the risk free rate is the return on a security or portfolio of securities that has no default risk and is completely uncorrelated with returns of any other assets in economy. The assets characterised by risk free rate of return shall also bear no reinvestment risk.

Commonly used treatment is to use the forecasted 52-weeks Treasury bills as a measure of risk free rate. The forecasted figures shall be used as to avoid the mismatch between the duration of risk free asset and duration of the valued asset/company's cash flows.

The other ways of estimating risk free rate that are however rarely used include 5- or 10-years Treasury bonds. The advantage of this approach is that the long term rate comes closer to matching the duration of the company being valued. The disadvantage might be the implicit inclusion of the liquidity premium within long term risk free rate [7].

Beta is a measure of systematic risk calculated for the projected Debt/Equity ratio for the company. In other words, Beta is a statistical measure of the variability of a company's stock price in relation to the stock market overall. Beta is calculated by using the regression of the percentage change in a stock or portfolio against the percentage change in the market. These might be applied using the following formula:

$$\text{Beta} = \text{Cov}(R_J, R_M) \,/\, (\sigma_M)\text{^}2 \qquad (2)$$

where:

$\text{Cov}(R_J, R_M)$ - covariance between stock returns (R_J) and market returns (R_M),

σ_M - variance of the market portfolio.

There are two ways of estimating Beta for the purposes of CAPM calculations:

- Beta based on comparable quoted companies' betas (benchmark treatment)

  Beta is calculated based on the betas of comparable quoted companies. The criteria for company's comparability shall comprise all the factors described in paragraph plus the requirement for the minimum stock listing period. As described in Fig. 11 while calculating beta the average period of 5 years shall be applied, although in extraordinary circumstances the period might be shorten to not less than 2 years (24 months).

  The steps that shall be performed in order to estimate beta for the valued entity (based on comparable quoted companies) are presented in Fig. 11.

  Before calculating the average unlevered beta, the individual's betas shall be unlevered using capital structures and effective tax rates of individual companies. The average unlevered beta shall be than relevered using the company capital structure and effective tax rate on annual basis throughout the period of financial projections.

- Beta based on industry average beta (alternative allowed treatment)

  An industry average beta is typically more stable and reliable than the individual company's betas.

  The steps that shall be performed in order to estimate beta for the valued entity (based on industry average) are presented in Fig. 12.

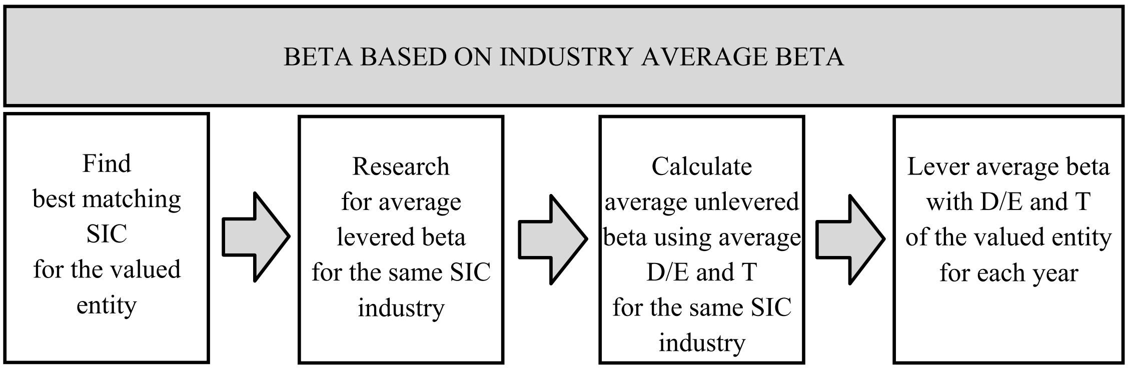

Figure 12. The steps that shall be performed in order to estimate beta for the valued entity (based on industry average)
(source: self study)

Industry average unlevered beta shall be calculated based on average industry leveraged beta and average capital structure and effective tax rates for the companies within industry. The average unlevered beta shall be than relevered using the company capital structure and effective tax rate on annual basis throughout the period of financial projections [4, 1].

The unlevered beta (asset beta) of a company is determined by the type of the businesses in which it operates and its operating leverage. In other words it is determined by the assets owned by the firm. Levered beta (equity beta) is determined both by the riskiness of the business the company operates in and by the amount of financial leverage risk it has taken on. Levered beta (equity) beta is affected by the capital structure of the company. In general an increase in financial leverage increases the equity beta of the company as the shareholders face more risk on their investment [4].

The operation of unlevering/relevering company beta (removing or adding the effect of capital structure on a company beta) is presented in Fig. 13

For comparable companies it is acceptable to use book value of debt, unless there is evidence that market value of debt differs significantly from book value of debt. In such case the average Debt/Equity ratio over the historical period of last five years shall be applied.

For each of the comparable companies used for estimation of beta, market capitalisation as of the closing date of company financial statements shall be used.

For comparable companies, last years effective tax rate shall be used, unless it differs significantly from the average effective tax rate for the company. In that case 5-years average tax rate shall be applied.

For valued entity current rate effective tax rate for every year of financial projections shall be used. It is necessary to ensure that consistent approach to all elements of beta equation is followed while unlevering betas of comparable companies e.g. if 5-years average Debt/Equity ratio is applied for company A (assuming material deviation from the last year Debt/Equity ratio is identified) then the same treatment shall be referred to company B.

Additionally the 5- or 2-years averages of Debt/Equity ratio might be also considered if material deviations in this ratio appear during the period of financial projections for the valued company.In general beta that is used in valuation shall be based on 60-months observation monthly return unlevered beta both in respect comparable companies and industrial average.

There are some empirical evidence that as an industry/company matures, its performance seems more like the performance of the overall economy. Although the adjustment of unlevered beta towards one over a longer period of time might be justified.

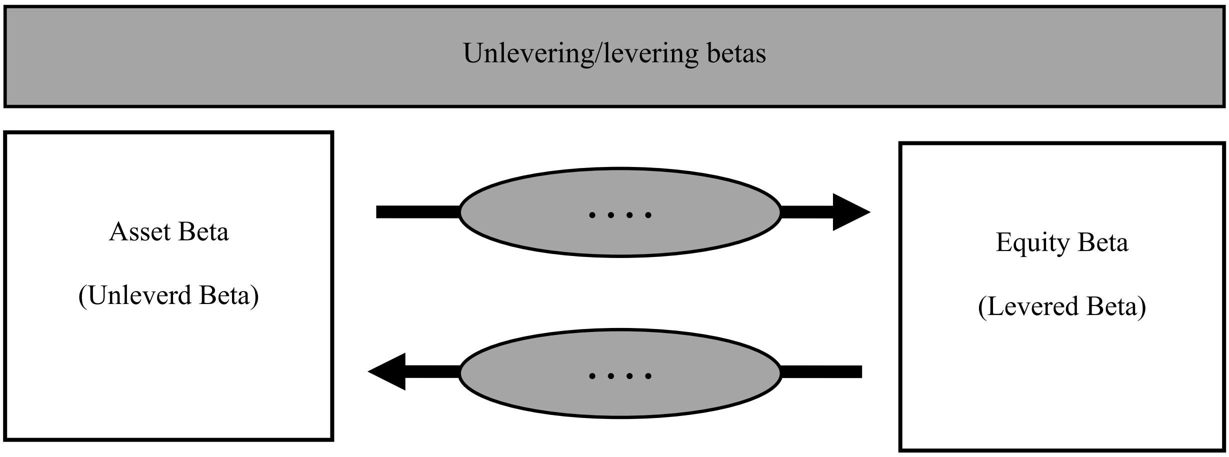

Figure 13. The operation of unlevering/relevering company beta
(source: self study)

The market risk premium is a measure of the return that equity investors demand over a risk-free rate in order to compensate them for the volatility/risk of an investment which matches the volatility of the entire equity market. In other words the market risk premium is the difference between the expected return on the market portfolio and the risk free rate.

In valuation practise theory, the market risk premium can be based on:

- historical data, assuming comparability of future and the past or
- forward looking analysis that attempt to forecast the market risk premium this figure in the future.

While performing valuation, the discount rate shall be equal to cost of capital of the company [3]. Valuation practice assumes estimating cost of capital using Weighted Average Cost of Capital (WACC).

WACC is the discount rate used to convert expected future cash flows for all investors. i.e. the rate that compensates the opportunity cost of both creditors and shareholders. The general formula for estimating after-tax WACC is simply the weighted average of the marginal after-tax cost of each source of capital:

$$WACC = C_E * (E / E + D + P) + C_D * (D / E + D + P) * (1 - T) + C_P * (P / E + D + P) \qquad (3)$$

where:

C_E - cost of equity,

C_D - cost of debt,

C_P - cost of preferred stock,

E - market value of equity (excluding preference shares),

D - market value of debt,

P - market value of preference shares,

T - effective tax rate.

There are only three types of capital included in formula. The actual weighting scheme can be more complex, because a separate market value weight is required for each source of capital that involves cash payments, now or in the future. Other possible items might include leases, subsidized debt, convertible or callable debt, minority interests, warrants and executive stock options, income bonds, bonds with payments tied to commodity indexes, etc. This approach provides technically correct estimation of WACC [8].

9 Final range of equity/company value

The final range of equity/company values is always derived as a sum of three main components:

- Discounted cash-flows within the projections period

  This is the sum of the normalised cash flows multiplied by the cumulative discount factor for each year of the financial projection period.

- Discounted residual value

  This is the sum of the normalised cash flows multiplied by the cumulative discount factor for each year of the financial projection period.

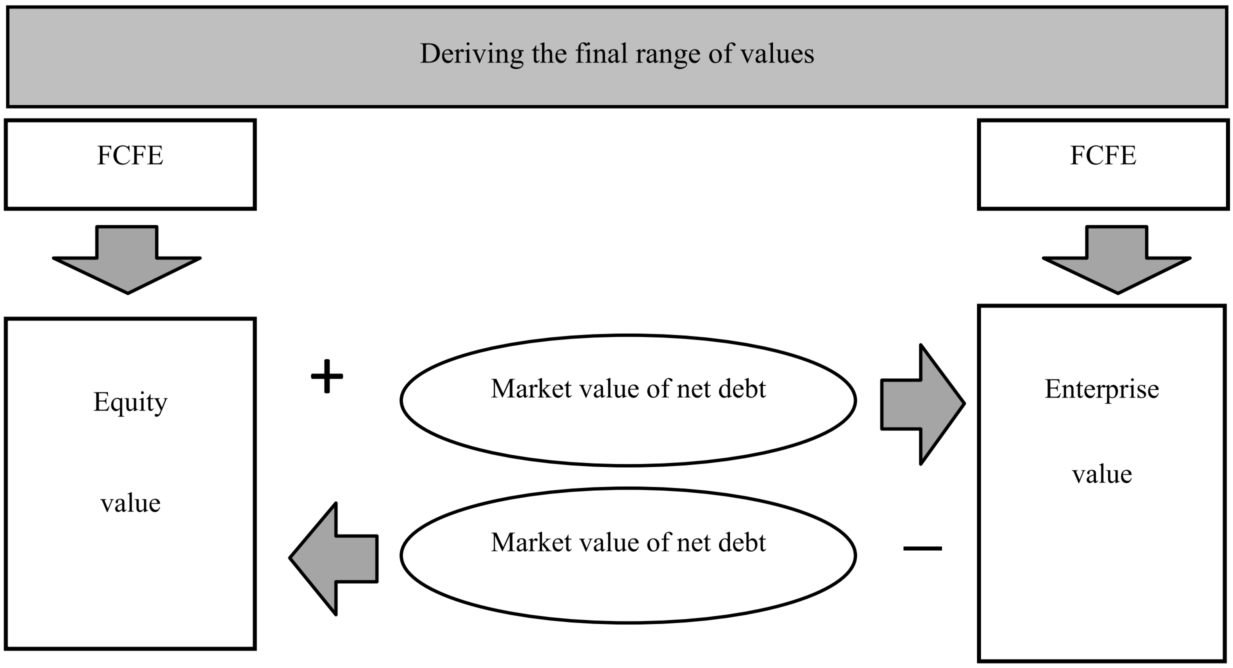

Figure 14. The conversion of valuation results using either FCFE or FCFF approach
(source: self study)

- Excess (non-operating) assets/liabilities

  This component includes non-operating assets or liabilities that were not reflected in the forecasted cash-flows but do have impact on the company value. The exemplary adjustments for excess (non-operating) assets/liabilities might include the following items:

  – excess cash as of the valuation date,
  – underfunded/overfunded pension liabilities,
  – market value of minority interests,
  – market value of non-consolidated subsidiaries,
  – off-balance sheet debt (if income associated with such debt is included in cash flows).

  The above list is not exhaustive and other potential adjustments relevant to specific situations should be discussed with team members.

While deriving the final range of values it is important to distinguish between the value of equity and the value of an enterprise.

In spite of the fact that both equity and enterprise value might be assessed using either FCFE or FCFF it is recommended to use FCFE for valuing equity and FCFF for valuing the whole company. Under certain circumstances e.g. very high financial leverage, significant changes in financial leverage within the period of financial projections or appearance of negative earnings for the significant part of the financial projections, it might be appropriate to value equity of the company using FCFF approach [6, 11].

The diagram presenting the conversion of valuation results using either FCFE or FCFF approach is presented in Fig. 14

10 Summary

The Discounted Cash Flow valuation reflects the ability of the company to generate cash in future. This methodology, in the best way, presents the real value of the company however it is very sensitive to the assumption that constitute the base of the financial projection.

Additionally DCF valuation is much more complicated than multiply or ANBV valuation what may be also concluded from this article that presents complexity of DCF valuation process.

DCF valuation also is used to present optimistic, pessimistic and realistic scenarios based on different set of assumption. Based on that it is reasonable to set a range of the company valuation.

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EVALUATION OF THE EFFECTS OF QUALITY MANAGEMENT SYSTEM IMPROVEMENT

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Abstract: The article presents the tools that enable organizations to assess the effects of improvement of the quality management system, such as internal and external audits; risk management, measures of effectiveness and efficiency of processes, evaluation of customer satisfaction, quality cost analysis; analysis of best practices and self-assessment. The effectiveness use of these tools depends on the progress of the efforts of organizations in activities related to its improvement, knowledge and skills of employees and managers, who should show the positive attitude of leadership and involvement.

Key words: quality management, audits, effectiveness of processes best practice analysis, benchmarking, quality costs, self - assessment, quality awards.

1 Introduction

Assessing the effects of improvement of the quality management system enables an evaluation of processes and products by comparing them with the organization's objectives, standards (technical and organizational), as well as with other organizational units of both internal (its business units, such as departments, establishments, trading companies within the holding company) and external (competitors or entities that achieve the best results in each process activity areas). Assessment activities allow the organization to examine deviations from targets (including management standards), and thus identify areas for improvement and identify opportunities for improvement through the identification of needs for the introduction of organizational innovation and (or) product. Evaluation of the organization's activities aimed at improving the quality management system can be carried out through:

- audit of quality management system,
- risk analysis and measurement of risks,
- measures of effectiveness and efficiency of processes,
- evaluation of customer satisfaction,
- quality cost analysis,
- analysis of best practices (best practice analysis or benchmarking),
- self - assessment (e.g. according to the guidelines of ISO 9004, quality awards and models such as the Malcolm Baldrige Quality Award (MBQA), Business Excellence Model (BEM, developed by EFQM- European Foundation for Quality Management).

Information obtained from these sources analyze the organization of periodic management reviews conducted by top management, which are used to assess the effectiveness of management systems.

2 Audit of quality management system

The effectiveness of the implementation, maintenance and improvement of quality management systems, occupational health and safety, information security, and sector - systems (i.e. HACCP, ISO /TS 16949), as well as other concepts to improve operational (such as the Toyota Production System, Lean Management or Six Sigma) is verified by independent study - audit. The audit of quality management system is to be understood as "the systematic and documented process for obtaining audit evidence and evaluating it objectively to determine the degree audit criteria” (ISO 19011:2003, p. 5). Audit records are evidence fact finding, or other information relevant to the audit criteria (for example, a set of policies, procedures, requirements) and other documents, which can be verified by an auditor during the audit.

Audit quality management system can be:

- internal - carried out by the company called for management review, or to achieve other domestic purposes,
- external - conducted by the certification body called third party.

Conduct audits and assessments, as the tools used in quality management, are subject to compliance with key principles of auditing, which include (PN-EN ISO 19011:2009, pp. 7-8):

- independence - the basis of impartiality in carrying out the audit and objectivity in formulating conclusions from the audit,
- evidence-based approach - the use of a rational method for obtaining reliable and reproducible audit conclusions in a systematic his trial.

Audit is to collect evidence (by listening to questions, and observation of employee behavior, verification of documents and records), designed to determine the extent to which the organization meets certain criteria (customer needs and expectations of other stakeholders, the requirements of organizational and technical standards, legal rules and goals, or internal standards set by the organization.

Companies may conduct on their own assessment in relation to their processes realized by internal audits (audits of the first page) or can be done with potential and current suppliers. Sometimes also to customers (other audits), such as in the case of a franchise agreement for the production of goods or services (e.g. a network of sales, service repairs, hotels, petrol stations). A special type of audits are carried out by independent external organizations such as the unit management systems certification (third party audits.) These units must have appropriate accreditation entitling them to issue the certificates (the product's compliance with regulatory requirements - e.g. technical standards), or the compliance management system with the requirements of relevant standards such as ISO 9001, ISO 14001, PN-N 18001, OHSAS 18001, ISO 27001.

The certification of quality management system may be also carried out on behalf of clients with independent audits of their suppliers. Both the audit of the first page, as well as third party (certification audit) in the assessment are taken into account the requirements of standards, which are implemented based management systems by organizations, as well as company - specific regulatory requirements, customer requirements (other stakeholders), and set goals. In the case of audits on the other hand are the basis for assessing the requirements for suppliers (and as already mentioned in the dependency set customers, e.g. in the case of franchise agreement). The assessment shall be subject to audits: documentation (documents and records) relating to products and processes, implementation processes, available resources necessary to meet the requirements set (such as staff qualifications, quality of infrastructure and working environment to ensure security processes and products), as well as employee behavior observed during the execution of activities in processes, as well as their awareness of organizational goals and applicable standards of conduct.

Audit is an integral part of the program management process audits. It consists of four phases (see Fig. 1), in accordance with the principle of W.E. Deming - the quality circles, in other words, the PDCA cycle (plan, do, check, act). Each of these steps, need to take certain actions, which completes the cycle of improvement of the audit program.

The scope of audit programs may vary depending on the size, nature and complexity of the organization. Regulatory requirements state that the factors influencing the scope of the audit are: purpose, duration, frequency of audit and the number, importance, complexity of the process of undergoing an audit.

Audit understood as to obtain an objective assessment appears to be sufficient to improve the quality management system according to ISO 9001:2009. The results of audits to be reviewed by the management company. Understanding the review can be static (compliance with standards) and dynamic (with the processes linking the environment). While the former are imposed, the latter are voluntary and represent a high knowledge of the managerial nature of quality management.

Treating the quality management system as an integral part of business management, you can ask questions about the effectiveness of this process. So far, it is assumed that the findings of the evaluation results are evidence gathered in relation to specific criteria, which may be procedures or requirements.

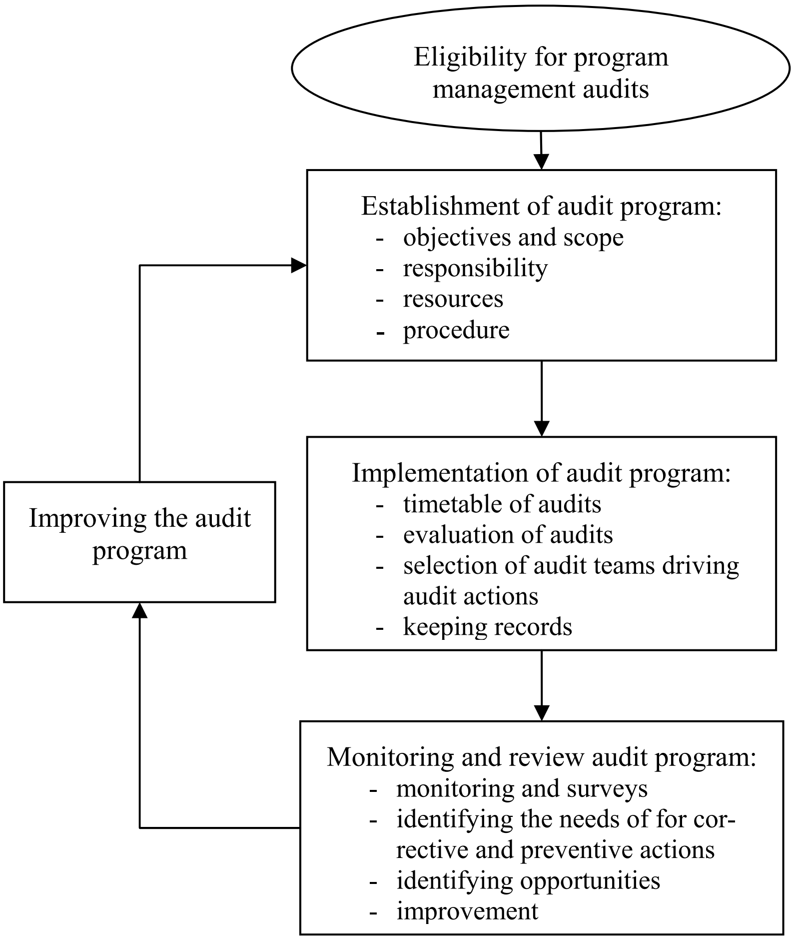

Figure 1. The process of audit program management
(source: own work based on the PN-EN ISO 19011:2003:9)

In this sense, the scope of the audit is limited opportunity to evaluate the effectiveness of the management system. Therefore, it should be noted that if the quality management system is an integral part of enterprise management system, it seems to be insufficient classically understood role of the audit. Evaluations can be completed to determine if there are no developments in the quality management system, the company investigated, which significantly threaten the improvement of its activities. The answer to that question may provide a more informative value than finding the fulfilment of the criteria for audit. It can be assumed that the probable is a situation in which the audit criteria are fulfilled and yet further improvement of the business is threatened.

Another issue is to determine:

- degree (or level) of the threat, because it determines the pace and nature of managerial decisions,
- qualified person or persons to conduct such an evaluation.

Therefore, the scope of the audit may be extended by evaluate the system, within the meaning of management sciences. Without a doubt the finding of serious threats to the improvement of the business indicates the special responsibility of the auditor for the correctness of that assessment. This requires a greater range of expertise (management, finance, marketing, quality) and rich experience, which is currently neither a requirement nor a recommendation contained in the PN-EN ISO 19011:2003.

However, among the principles of auditing, special attention in the context of the presented considerations, in addition to ethical conduct, professional diligence, independence, deserve the following principles: the fair presentation (reflecting the state of affairs) and an approach based on evidence (the audit evidence should be verifiable).

They are important because of the significant impact on the assessment of the effectiveness of quality management system and improve their diagnosis. Informing the customer (organization or person who receives the product) on the identified risks is intended to protect the interests of all beneficiaries of the enterprise, and thus is a prerequisite for security of the entire system of governance. If the structure of the audit objectives due to the needs of all stakeholders, it highlights another aspect of the expanded role and scope of audits carried out in the company. It is not merely about compliance of the quality management system requirements for regulatory or other action under the law, but also on its external and internal dimension in terms of governance, including in relation to the concept of value based management (VBM - Value Based Management), corporate social responsibility (CSR - Corporate Social Responsibility) and risk management. This represents a further justification for the claim that the auditing system should be oriented not only how to make standard on its effectiveness, but primarily on its effectiveness is related to the management system approach.

3 Analysis and risk measurement

Guidelines for auditing quality management systems, environmental management (PN-EN ISO19011: 2003) provide auditing principles, describe the actions and establish auditing and assessment of competence of auditors. However, there is no indication whether the analytical tools of vocations to the risk of loss of the ability of the system to improve it. Thus, it seems to be the development of risk assessment models, which reflect its nature, in terms of requirements of quality management system (PN-EN ISO 9001:2009). According to the concept of risk management, to measure the risk in situations of decision making on an ongoing basis to provide appropriate financial models and procedures for their application. The concept of risk model refers to the results achieved by the identification, evaluation and risk measurement.

The basis for the construction of such models is the classification of risks, using appropriate qualitative and quantitative methods. Risk management is generally understood as a process of methodical problem - solving organization associated with the risk (for the treatment of risk) in such a way that these actions brought lasting benefits to all stakeholders. It is a system of continuous, planned and continuously refined covering both the organization's strategy and organizational procedures. This means that each identified risk in the form of business should be described in detail and continuously monitored based on specific indicators. Risk factors in terms of management can be divided into two main groups:

- external, which consists of risk: operational (legislation), financial (foreign exchange), strategic (fluctuation in demand, changes in subjective structure of the market) and risk (contracts, property),
- internal, which for example include: liquidity, cash flow, information systems and intellectual capital.

Scope and classification of risk factors are not, necessarily, the same for all companies. The variables include industry, company size, type and size of product groups, the scope and potential of markets (actual and potential). Examples of groups of risks can be:

- financial (loss of long - term contracts, cash - flow difficulties, excessive share of loans in the financing of long - term liabilities),
- operational (no license, the difficulty in obtaining raw materials, loss of productivity),
- organizational (conflicts with groups of staff, fast rotation at workplaces, lack of job descriptions, low level of ethics),
- competitive (inflation, changes in legislation, mergers and acquisitions, strategic alliances, technology transfer).

As is clear from the examples, it is possible to create a classification of risk groups and factors, the factors that may occur singly or in combination; a specific activity will be related to groups and risk factors. However, the importance of factors may be different depending on the industry and the environment in which the company operates. To determine the risk factors and how its measurement can be used recordings of ISO IEC TR 13335-3:1998, which relate to the following methods:

- A matrix of previously defined values - physical assets are valued at replacement cost, or play. Then the costs are converted to a qualitative scale, which are included levels of vulnerability and risk, and the resulting level of risk, rank the threats according to the degrees of risk - linking with each other consequences (the value of assets) and the likelihood of risks (including the vulnerable) and to determine the appropriate level of risk (in the order of priorities).

- Estimate the frequency and potential harm caused by risk - estimated value for each asset and the risk of the combination of which determines the result for each asset. When all the results of the assets for a given system is possible to define risk levels, which is exposed to this system.
- The difference between a roar as possible and unacceptable - risk measures are used only to his rank, thus indicating the place where the need for action is most urgent, and the same can be done with much less effort.

In addition, special attention should be paid danger of a qualitative nature. Financially irrational, in short periods of time, quality management, and developing relationships with clients intuitively to affect the assessment system's ability to improve, but there is no simple measurement apparatus. Market analysis provides the basis for determining the prospects for improvement, but without the continuous analysis of environment is substantially deficient.

Significantly, increase the probability of significant disturbance of the system is generally the result of the cumulative reduction in the pace of development of the system, but the negative phenomena in the surrounding businesses, the impact of which has not been adequately reflected in the award system.

The separation of the quality management system to market conditions, maladjustment causes expansion gaps (mismatches) of system solutions to the required level of quality management. In this sense, the quality management system can significantly limit the opportunities for flexible business operation.

Although essential to predict the difficulties to be encountered by auditors in evaluating the quality management system to improve mostly to be a situation in which there is no clear distinction between the situation in which the risk factor does not signal a threat and the situation still pointing to such a threat. This implies a need to assess the conditions of uncertainty associated with the lack of precise information.

Ambiguity is inherent feature of such notions as:

- appropriate level indicators,
- the level of risk corresponding to loss of ability to improve a specific configuration of risk factors,
- significant risks the development of improvement.

It is said that the essence of quality management system is improving in the sense that the system in the long term is to contribute to the development of relationships both externally and internally, but also to increase its efficiency, which in turn reduced to the concept of efficiency throughout the organization and specific benefits for beneficiaries (see Fig. 2).

You could say that the comparison of states: the benefits and requirements of all stakeholders is the basis for determining the real factors and measures for quality management. However, business is improving its platform.

Without a doubt, a statement of risks requires the application of additional procedures activities, which are based on action plans in the enterprise, designed with a view to prevent the loss of the system's ability to hone in on one side. On the other hand assessment of the feasibility of these plans and their impact on improving the situation of the company.

Thus increasing the responsibility of the auditor, as yet such plans are not part of system documentation. Non - disclosure by the auditor of such hazards and their potential effects on the audit report, this is definitely proof that the principles of corporate social responsibility or are not established, or are not respected. Of course, we can assume the existence of cases in which the type and number of threats is high, and despite this degree of uncertainty as to the improvement of activity is low. In the case of monopolistic competition is acceptable. But we can also assume that this is not a common situation in the market, so this situation is a special case.

Recently, you may notice that more and more forms of acts associated with systemic risk management. These activities should be an ongoing process and developing process, which includes the organization's strategy and tools for its implementation. In this process should be postponed assumptions contained in its strategic goals into specific objectives at regular department's processes, and tasks for team or individual workers. Furthermore, the introduction of risk management involves the identification of operational procedures (taking into account the standard setting rules

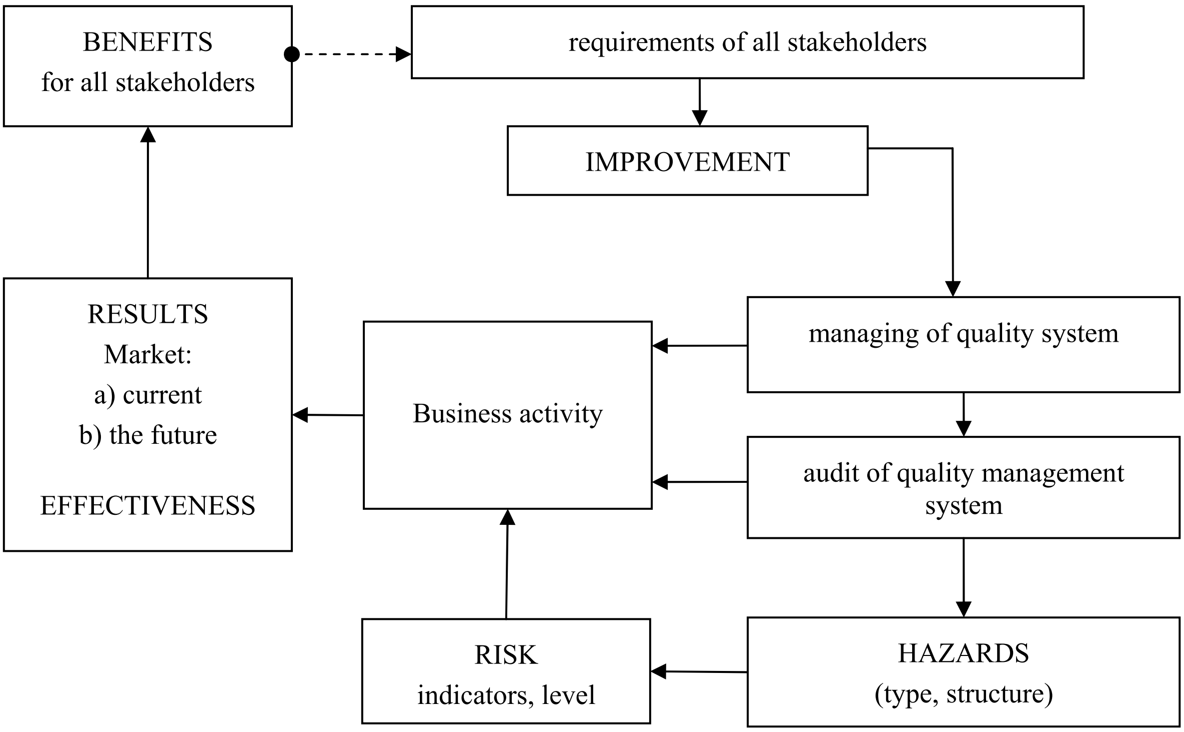

Figure 2. Risk as element of quality management system
(source: own work)

of conduct, which can prevent incompatibilities and the procedure should they occur), accountability for results, monitoring and evaluation of achievements. Risk management, is based on the concept of continuous improvement and include the following steps (Urbaniak [12], pp. 157-170):

- term goals of the organization,
- identification of risks and their sources (causes),
- risk analysis (by mapping efforts to identify risk areas and sites of potential hazards, their description and measurement),
- assessment of risk (the probability of its occurrence and impact on the achievement of those objectives), the effectiveness of the means and methods of surveillance operations to control risks (the level) and reduce the effects of its influence,
- definition of objectives aimed at reducing risk and providing resources,
- define rules of conduct (procedures, contingency plans, record),
- information on the risk by raising the awareness of employees and other stakeholders,
- achievement of objectives through operational measures aimed at reducing the risk by taking corrective action, preventive and improvement measures to streamline procedures for risk management (focusing on reducing the level currently affecting the identification of new risks and threats and their sources).

These procedures relate to the methodology followed during the identification of risk, its analysis, the implementation of preventive and corrective actions taken to reduce (reduce) the impact of adverse events, monitoring the level of hazard, assess the effectiveness of safety management system. Improving quality management system through the use of risk management approaches companies use such guidelines contained in the example:

- Guide 73 - Risk Management. Vocabulary. Guidelines for use in standards, ISO IEC 2002,
- A risk management standard, IRM/ALARM/ AIRMIC, FARM, Brussels, 2002,
- AS/NZ 4360:2004 Australian/New Zealand Standard for Risk Management,

- Risk Management: Guideline for Decision-Makers- A National Standard for Canada, the Canadian Standard Association, 2002,
- The Orange Book, Management of Risk - Principles and Concepts, HM Treasury, London 2004,
- Enterprise Risk Management - Integrated Framework, COSO II, 2004,
- The EFQM. Framework for Risk Management. Driving Excellence in Risk Management, DNV-EFQM, Brussels 2005,
- TR 19:2005: Technical Reference for business continuity management,
- BS 25999 - 1:2006 Code of practice for business continuity management,
- BS 25999-2:2007 Business continuity management,
- ISO 28000:2007 - Specification for security management systems for the supply chain,
- Management of Risk: Guidance for practitioner, the Office of Government Commerce, The Stationery Office, London, 2007,
- ISO/PAS 22399:2007, societal security - Guidelines for incident preparedness and operational continuity management,
- CSA Z1600 Standard on emergency management and continuity programs (draft standard for the Canadian Standards Association),
- ISO 31000:2009 Risk Management. Principles and Guidelines on Implementation.

One of the most commonly used tools that can identify threats in an enterprise risk processes and products (as well as to determine the possibility of their detection and potential impact and importance to the company and customer) and the design methodology of preventive and corrective actions are FMEA (Failure Mode and Effect Analysis). The identification of risk, you can also use relatively simple techniques such as flow diagrams (called flowcharts), lists - check cards (check sheets), mapping of processes (called process mapping), cause - effect diagrams (called cause and effect diagrams) or slightly more advanced as technology - based decision tree based on whether the study of hazards and operational capability (Hazard and Operability Study, HAZOP).

Implementing the concept of risk management companies devote special attention to the operational tasks associated with processing customer orders (order handling, purchasing, design, manufacture the product or service, delivery and service activities) and assisting (supervision of infrastructure, financial management, human resources, and environment work). Their effective implementation determines the continuity of the organization. You can also see that more and more some of these processes are performed by external entities. The effect is that the companies buying these services work out a methodology for the qualification and periodic evaluation of suppliers, is also expecting their suppliers to implement risk management approaches.

The effects of the implementation of risk management approaches undoubtedly depend on the effectiveness of communication processes with stakeholder's organizations (especially the owners, customers, suppliers, employees). Of particular importance is creating awareness of the risks of the owners and their sympathy for the decisions taken by the management of business units focused on making investments in order to prevent threats. Building partnerships with customers and suppliers allows for time-synchronized and standardized processes of planning, ordering, designing, manufacturing, quality control and supply of products, and thus the formation of non-compliance products and organization. Raising employee awareness of the risk requires the implementation of periodic training and exercises to allow for an effective implementation of procedures related to their hazard identification, response to emergency situations and effectively eliminating their effects.

4 Operational improvement measure indicators (assessment and process efficiency)

Improving the business is possible only if it rests its decision on an analysis of operational activities. Such analysis is carried out, mostly with the use of metrics, so you can monitor both the current state of the implementation process and evaluate the results (achieved ratios) with the planned objectives (target indicators). With this analysis can provide direction for further action for the entire company and its units. Meters operating activities, can be divided into the following generic groups:

- financial, for example, variable costs, fixed costs, profitability, capacity, profit,

- time, such as the length of the production cycle, product delivery, the time for a new product,
- quantitative and qualitative, such as the level of deficiencies, the number of complaints, production capacity, efficiency, productivity,
- flexibility and innovation, such as adjusting to changes in the environment and to demand, improving the skills of workers, flexible equipment in the means of production,
- social, such as division of labour (fair), ergonomic shape of the job, sense of job security,
- organic, such as the environmental burden of harmful emissions, consumption of natural resources.

To assess the operational processes and identify areas that need improvement, you can use the capacity or efficiency measures (Witt [14], p. 251). Capacity means the maximum quantity that can be produced in a specified time, utilization, specifying the amount of available capacity - e.g. manufacturing, warehousing, which is actually used (usually expressed as a percentage it is). Efficiency expresses the ratio of the current level (e.g. production) to the size of the achievable.

5 Measuring customer satisfaction

The requirements of quality management standards require the measurement of the degree of improvement of the organization by carrying out assessment of customer satisfaction. For this purpose, both methods of qualitative and quantitative.

The first flu can include the method of the questionnaire (using a questionnaire sent by mail, fax, e-mail), telephone interviews, personal interviews, as well as formal and informal opinions expressed.

The second group, should be classified as quantitative measures of such increase in sales value (in a given period), the percentage of re-purchase, the share of regular customers (loyalty indicator), the duration of business contacts, share further recommendations, the number of repeat purchases, the number and value of claims, shares market, loss of customer (the outflow rate of customers), the new clients.

The most common measure used by firms is the number and value of the claim. It must be regarded, as targeting the expression of dissatisfaction concerning the organization of (and often items of maintenance, or supply, such as timeliness, documentation, terms of pricing, service), or the process for dealing with complaints, which is expected or required response occurred explanatory problem and or proposed solution is its the process for dealing with complaints is a particularly sensitive and requires very precise definition of rules for communication with clients (Vos and Huitema [13], pp. 8-17).

In dealing with requirements of International Standards Organization has identified guidelines contained in ISO 10002:2004 (Quality management - Customer satisfaction-Guidelines for complaints handling in Organizations). Standard provides guidelines for designing and implementing an effective process for dealing with complaints for all types of transactions, including e-commerce. The information obtained in the process of dealing with complaints can be a source of improvements to the products and improve the image of the organization in the eyes of its customers (Hughes and Karapetrovic [4], pp. 1158-1175).

6 Evaluation of the organization's activities through the analysis of quality costs

The first studies on issues related to the cost of quality arose in the thirties and fifties of last century. Forerunners in this respect were, inter alia, Shewhart [7], Juran and Gryna [6] and Feigenbaum [2]. In the literature, there is no conclusive approach to the division of quality costs. Quality cost analysis can be conducted in a variety of approaches such as Stimson and Dlugopolski ([9], pp. 26-31); Sower, Quarles and Broussard ([8], pp. 121-140):

- analysis of the costs of prevention, assessment and gaps (PAF – prevention, appraisal and failure cost model),
- analysis of the costs of compliance and non - compliance (model PCM - Process Cost Model),
- analysis of the costs of internal and internal,
- analysis of costs by the life cycle.

The purpose of the cost of quality by Juran J.M. is (Szczepańska [10], p. 262]):

- identify all the types of actions and activities which lead to the achievement of the required product quality, regardless of their organizational division within the organization,
- determine the cost of operations and activities,
- interpreting information received makes it available to all concerned,

Table 3. Optimum cost of quality
(source: Szczepańska [10], p. 265)

Zone projects to improve		Neutral zone		Excellence zone	
cost of defectiveness	> 70%	cost of defectiveness	~ 50%	cost of defectiveness	< 40%
assessment costs	~ 20%	assessment costs	~ 40%	assessment costs	~ 50%
prevention costs	< 10%	prevention costs	~ 10%	prevention costs	> 10%
deficient	100%	quality	100%	good	100%

- seek opportunities for cost optimization of production quality,
- organizing the current trends, observation and recording quality for the cost of a product or service.

Based on studies conducted in recent years by the Feigenbaum AV. costs of non-compliance can be estimated at 23% of sales, of which approximately 50% are costs of internal errors, 25% of the costs of external errors, about 20% of the costs of evaluation, and the remainder (approximately 5%), baskets of prevention (Feigenbaum [2], pp. 22-27). Analysis of quality costs should allow the definition of zones of quality costs, which include: neutral, excellence and improvement projects (see Table 3). The share of costs in the total cost of sub - quality sets the zone to which you can qualify for the cost of the quality of a company, namely:

- Costs in the zone projects to improve - the production costs of defective exceed 70% of the total cost of quality, and prevention costs represent about 10% of the cost, with 20% share of the cost evaluation. With this level of costs, the company should establish a program to improve (lower level) the cost of quality.
- Costs in the neutral zone of the production defective is about 50% of the total quality costs, prevention costs represent about 10% of the costs, the assessment costs fluctuate around 40% share of the cost. So a certain level of costs is considered to be quality, and the efforts of companies should be focused on quality control techniques.
- In the area of excellence, cost of production of defective not exceed 40% of the total cost of quality and costs of preventing an approximately 10% of the cost, with a 50% share of the cost of evaluating the cost structure. Companies with this level of costs should optimize quality costs by continuing to look for opportunities for reductions (audits, audit), the word continued process of continuous quality improvement.

Analyzing the relationship between the types of quality costs is also a pattern that the cost of reducing the level of non - compliance requires enterprises to bear the expenses for activities related to the control and prevention. The effectiveness of these measures should lead to lowering the total cost of quality.

7 Benchmarking practices best analysis

One of the conditions for continuous improvement of quality management systems is to analyze best practices often equated with a comparative evaluation or benchmarking. According to the definition proposed by the American Productivity and Quality Center. Benchmarking is a continuous and systematic performance measurement and comparisons of organizational processes in relation to the leaders in order to obtain information which will enable the organization to take certain actions involving the adaptation of best practices to increase their competitiveness.

Benchmarking is mostly define as a continuous systematic process, which consists in confronting their own effectiveness as measured productivity, quality and experience with the results of these companies and organizations that may be regarded as a model of excellence.

Most comparative evaluation starts from a comparison with the procedures of the process of global leaders and organizations identify strengths and opportunities for improving it. In addition to analyzing the products, processes and performance, this evaluation helps determine the causes of gaps that exist between products, processes, and performance of the company and used by world leaders.

Conducting comparative assessments allows businesses to identify practices used by other organizations (through the use of specific techniques for collecting information), get to know them and (in many cases) to adopt to improve their operations and improve (or fix) for it its competitive position (Haverty and Gorton [3], pp. 1077-1091). As for the best, the source may be an effective tool in the process of streamlining the processes indicated in conversations with customers and process mapping.

Benchmarking based on surveys that may be undertaken through telephone interviews during the conference, or by using the techniques of video inter-views conducted by correspondence for via mail and fax calls and during mutual visits, which make it possible to talk "face to face", and hands-on atmosphere and conditions of work in an environment benchmarking partner. Apart from the above research techniques in order to conduct comparative assessments are also used focus group interviews and other sources of information (e.g. reports, notes and newspaper articles). The process of benchmarking can be carried out within their own organizations, between subsidiaries of the group, within the holding companies, departments and functional areas of business. In many companies (especially international corporations), the comparison with the best starts of the internal benchmarking between business units.

A second option is to compare the analysis of competition in the sector. The subject of comparisons are carried out not only the quality parameters of products but also the efficiency and effectiveness of management processes, as well as perceived by customers criteria for the competitiveness of firms and their suppliers (compliance with the specifications of the offered quality - defective supply, product innovation, competitive pricing, timely delivery of orders, after - sales service, speed of response to inquiries and complaints, the powers of the sales and service personnel, compliance of documents with the delivery, performance management system and quality control, production capacity, offered terms of financing transactions, qualified managers) (Jang [5], pp. 919-930).

A third variant of the benchmarking study is to compare in terms of functional organization of the company, used management methods, strategies and specific activities such as focused on building quality systems, continuous improvement and learning benchmarking between companies from different sectors. Benchmarking not only apply the big giants, but also a method that is starting to spread in medium and small enterprises. Reference points in the comparative analysis may be: the technical quality of products (in relation to the technical parameters, modern solutions, the implementation rate of innovation), logistic processes (mostly on time delivery and flexibility), service activities, modern technological processes, the effectiveness of communication with customers, of the business to the environment (e.g. environmental protection, sponsorship, investing and creating new jobs), the perception of activities and communication companies (with particular emphasis on advertising, public relations), reference the company's competitiveness to stimulate buying behavior of buyers (to identify the major strengths affecting selection of the company as a supplier (e.g. elasticity, individualization of solutions, awareness and brand image), evaluation of personnel responsible for customer contact (professionalism, culture of service, completeness of the information, the speed in response to customers).

8 Methods of self - assessment and quality awards

The degree of improvement of the quality management system can be subjected to self or verified by seeking organizations to grant awards of quality. These awards are both at the international level (e.g. the European Quality Award, Prize Deming), national (e.g. the name of Malcolm Baldrige Award, Japan Quality Award, Polish Quality Award), regional and corporate (e.g. Philips Business Excellence, Tata Business Excellence Arumugam ([1], pp. 46-58). Overview of the winners and finalists of quality awards, points out that:

- in the European Quality Prize awarded in the years 1992-2008, was dominated by companies from Britain, Spain and Germany. Another country is Turkey, which has eight companies laureates,
- in the W. E. Deming Prize granted in the years 1951-2008, was dominated by Japanese industrial companies, however the largest number of winners of the companies concerned: Nippon, Toyota and Aisin,

- M. Baldrige Prize awarded in the years 1988-2008, was dominated, in addition to industrial enterprises, companies representing the service sector (15), health care (8) and education (7),
- in the Polish Quality Prize, awarded for the years 1995-2008, was dominated by industrial companies, service (28) and public (25).

Criteria used in evaluating applicants for these awards are also for many organizations guidelines for improvement (e.g. they are self - assessment). These are complex models (also known as models of excellence, called excellence models), covering a wide spectrum of areas including but not limited with strategic planning, leadership, knowledge management, process management, customer relationship management and suppliers. It allows companies to identify opportunities for improvement in planning their development, resource development, implementation and performance.

Developing self-assessment, in the practical activities of the organization, bringing a number of tangible benefits, which are (Szczepańska [11], p. 343):

- disciplined and structured approach to improvement activities,
- an assessment based on facts and not on individual perceptions,
- consistency of directions in determining what should be implemented,
- integrating the various initiatives pro - quality with operations and processes,
- effective diagnosis,
- objective assessment in relation to a set of criteria,
- stimulant for the improvement of the management, focusing on areas where these improvements are the highest priority,
- methodology for use in all areas of management - from a particular organizational unit until the entire organization.

Collecting and analyzing data by companies when carrying out self - assessment is increasingly using modern information technologies to enable effective use of them to make decisions related to the improvement of the operational organization. Applicants for the award, individuals must also be characterized by making efforts in the development of human resources by raising their level of competence and motivation of workers (allowing them to effectively solve problems and implement corrective and preventive action, as well as a source of product innovation and organizational).

9 Summary

As can be seen from the foregoing considerations, the ways and methods for evaluating the effects of improvement of the quality management system should be included in a coherent system of measurement. Otherwise, evaluates the effects are only some improvement. It does not give a full picture of developments in the management of the company quality system. However, a comprehensive evaluation of the effects of improvement requires adequate data to conduct it. Without a doubt, it is also time-consuming. As shown by practical examples, mostly in enterprises is used in the evaluation of audit and evaluation by customers. This demonstrates the limited approach of companies to improve the comprehensive assessment of the quality management system.

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