ISSN 2080-7279
2012 Volume 04 Number 01

foundations of management

1/2012

INTERNATIONAL JOURNAL

WARSAW UNIVERSITY OF TECHNOLOGY
FACULTY OF MANAGEMENT

Foundations of Management

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Frequency: Published four issues per year; two regular and two special issues prepared by invited editor(s)

Internet: The International Journal - Foundations of Management is currently available on-line at:
http://www.fom.pw.edu.pl/s110/foundations-of-management
http://bcpw.bg.pw.edu.pl/dlibra

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ISSN 2080-7279

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 synergy between two parallel trends in managerial sciences: social and economical. Social trend originates from economic universities and academies and the engineering trend comes from factories and technical universities.

Three of the great representatives of the engineering trend in managerial sciences on the break of the XIX and XX century, all created the universal foundations of the management sciences: American Frederic W. Taylor (1856-1915) – developer of high speed steel technology and the founder of the technical and 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 timescale system elements scheduling theory and diagrammatic method as well as the basics of the division of work and specialization.

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 – all 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.

Through publishing the Foundation of Management we would like 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 will adapt to current trends because of wanting to answer to the changing economic and social challenges in the integrating Europe and World.

Tadeusz Krupa

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THE JAPANESE MODEL OF KNOWLEDGE MANAGEMENT

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***Abstract**:* The effectiveness of Japanese management methodologies is making them increasingly popular with business organisations all over the world. This paper aims to present one of the least known knowledge management theories: the knowledge creation model by I. Nonaka and H. Takeuchi. In their approach to the theory of organisational learning and knowledge creation, Nonaka and Takeuchi propose a categorisation of knowledge into tacit and explicit (formal) knowledge and explore the relationships between knowledge production, transfer and application; they also address the issue of applying existing and creating new knowledge. Presented SECI model captures the conversion of tacit knowledge into explicit knowledge in four steps: Socialisation, Externalisation, Combination and Internalisation. The paper examines case studies that illustrate the practical application of the processes.

Key words: knowledge management, tacit knowledge, explicit knowledge, model by I. Nonaka and H. Takeuchi, knowledge spiral.

1 Introduction

Japanese management methodologies have widely been credited for the spectacular global success of numerous businesses from the *Land of the Rising Sun*. Concepts and techniques such as *Total Quality Management* or *TQM1*, *Kaizen*, *Kanban*, *HOSHIN* or *Hoshin kanri*, and *Just in Time* have been recognised and implemented in organisations in many different cultures and geographies since the 1970s.

Japanese management methodologies are standardised, procedure-driven and based on 'regimes'. As such, they are usually quite difficult to transplant directly in their indigenous form to European or American business organisations which tend to have a radically different corporate culture. These methodologies offer a unique approach to people motivation and there is a great emphasis on professional development, demonstrating individual innovation and creative thinking. Well developed and loyal human resources are considered to be among the most valuable assets. Customer and supplier relations are based on close relationships and collaboration. This offers a competitive advantage driven by high quality products, strong productivity, short lead times and low costs. Organisations which are not powerful market players with access to vast capital resources may still become very successful by putting in place many of these principles. Being observant and making adjustments to everyday operations will usually be enough. Knowledge management will be much easier in organisations which operate to these principles and have established such practices.

Knowledge management is not just about strategy, however. It is based on well identified and analysed available and critical resources. Knowledge is one of such critical resources in an organisation. Incremental steps must be taken to implement measures and processes to achieve the goals and objectives of the organisation. Knowledge management leads to the deconstruction of stereotypes in order to accomplish measurable success[2]. A new management philosophy is required, which offers a new mind set and a new way of interpreting social, economic and corporate developments. A paradigm shift in management is essential to break away from traditional and, indeed, obsolete ways. Knowledge management offers itself as the new paradigm in business.

In knowledge management, it is the human resources that have attracted companies' and event countries' attention as a possible source of competitive advantage. In fact, countries can develop their own research and development potential and take advantage of the

[1] Quality Management as a method of organisational improvement was developed in the U.S. by E. Deming. Since his ideas were not embraced by American businesses at the time he promoted them in Japan. He is believed to be amongst the architects of the Japanese economic miracle as TQM found its way to many different sectors in the 1960s.

[2] T. Kuhn - *The Structure of Scientific Revolutions.* New American Library, New York 1986, preface.

opportunities offered by modern information and computer technology[3].

L. Edvinsson observes that 'knowledge has become the main source of wealth not only at the level of organisations but also countries'[4]. However, knowledge if not applied in manufacturing and services will not by itself drive economic growth; high technology, mainly information technology, is merely a tool or a means to achieve the end.

There is an increasing amount of criticism towards traditional management concepts and models. The world is transforming, the era of mass manufacturing, autocratic management, 'silo' and fixed structures is coming to an end. Management practice is affected by changes in global systems, macroeconomic and competitive environments and evolving business organisations. Organisation's dependence on the external environment has become self-evident. The dynamic of environmental transformation is growing faster and brings business to a whole new level. This is manifested by the reconfiguration of needs and the expected ways of satisfying them by businesses. Past experience and existing procedures are rendered irrelevant and there is a strong pressure for new behaviour. There is an incessant demand for new and effective business management techniques.

Not all Japanese management methodologies are new but they are certainly new to Polish entrepreneurs. With their corporate culture, people motivation systems, employee innovation and creativity, continuous improvement and people perceived as a strategic asset, Japanese companies are well equipped to embrace knowledge management.

[3] J. Woroniecki - *Nowa gospodarka: miraż czy rzeczywistość? Doktryna, praktyka, optyka OECD* (New Economy: Mirage or Reality? OECD Doctrine, Practice and Perceptions) [in] Gospodarka oparta na wiedzy. Wyzwanie dla Polski XXI wieku (Knowledge-Based Economy. Challenges for Poland in the 21st Century) (ed. A. Kukliński), Committee for Scientific Research, Warsaw 2001, p. 48.

[4] L. Edvinsson - *IC Entrepreneurship for Knowledge Capital as the New Source of Wealth of Nations* [in] *Intellectual Entrepreneurship through Higher Education* (eds. S. Kwiatkowski and J. Sedlak). Publishing House of the Leon Kozminski Higher School of Enterprise and Management, Warsaw 2003, p. 21.

2 The essentials of the knowledge management model by I. Nonaka and H. Takeuchi

I. Nonaka and H. Takeuchi observe that while knowledge is at the centre of attention in business organisations and in society no one has yet examined the mechanisms and processes of knowledge creation[5]. However, everyone agrees that managing knowledge is very much different from managing tasks, functions or people and that it requires a special approach to:

- strategy,
- organisational structure,
- communication systems,
- human resources policy,
- management skills.

The point of departure for I. Nonaka and H. Takeuchi is the classification of knowledge into 'tacit' and 'explicit' (formal), as suggested by M. Polanyi[6].

Knowledge is created as a product of interactions between people and this is how tacit knowledge turns into explicit one. Explicit knowledge is structured and formalised; it can easily be transferred to others and shared. It takes a number of different forms such as books, documents, specifications, manuals, mathematical theorems or network resources.

Tacit knowledge is related to an individual who possesses it and it is hard to formalise and transfer it to others. This type of knowledge may be captured in the following statement: 'we know more than we can say'. Tacit knowledge is 'intangible', difficult to express and very individualised and related to the person's accumulated experience in various areas of human endeavour. Tacit knowledge can be expressed not so much by words alone but also by idiosyncratic actions that have to be practiced and taught to the 'uninitiated' in order to help them learn to copy them. Tacit knowledge is made up of thought models, beliefs and preconceived notions so deeply rooted in our minds that we take them from granted, which makes it ever so more difficult to articulate them[7].

[5] I. Nonaka, H. Takeuchi - *Kreowanie wiedzy w organizacji. Jak japońskie spółki dynamizują procesy innowacyjne* (The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation). Poltext, Warsaw 2000, p. 24.

[6] M. Polanyi - *Personal Knowledge: Towards a Post-critical Philosophy*. Routledge & Kegan Paul Ltd., London 1958.

[7] I. Nonaka - *The Knowledge-Creating Company* [in] Hitotsubashi on Knowledge Management (eds. I. Nonaka, R. Toyama, N. Konno), John Wiley & Sons, Singapore 2004, p. 98.

Specific tacit knowledge may be acquired through shared experience or by being close to its holder. Metaphors, analogies and associations, being part of the language, may lead to understanding, and consequently to the acquisition of tacit knowledge.

The classification of knowledge into two forms is the basis for knowledge creation in the company, i.e. the conversion of knowledge through management processes, the organisational context of knowledge acquisition and processing, the places of knowledge creation and defining the knowledge assets.

I. Nonaka and H. Takeuchi are considered to be representatives of a coherent and systemic approach to knowledge management. They recognise two important perspectives on the practical application of knowledge:

- the interdependence of knowledge creation, transfer and application,
- the use of existing knowledge and the creation of new knowledge[8].

The knowledge management process is a linear sequence starting with creation, through transfer all the way to application.

Another process is an interactive one and it involves such knowledge management processes that recognise multidirectional relationships between elements. According to M.H. Zack, the capacity to take advantage of existing knowledge and to generate new one requires exploitation and exploration[9]. Creating new knowledge is to be a long-term strategic goal and most activities in an organisation must be focused on exploiting the existing knowledge, i.e. on the short-term operational objectives.

Knowledge has a characteristic of being complex, hard to absorb, transfer and apply. In contrast to other resources, knowledge is dominant, inexhaustible, simultaneous and non-linear[10]. It dominates because it is a top priority resource. Unlike other resources in organisations, it cannot be exhausted because the more it is used the higher its value. Simultaneity results from the fact that it can be used by multiple people in different places at the same time.

Non-linearity implies a general pattern: a small input of knowledge may make a major difference or the same 'dose' of knowledge applied in one organisation may yield different results than if applied in another. The above characteristics of knowledge make it a unique resource which requires a unique approach.

I. Nonaka and H. Takeuchi point out that the exploitation of knowledge in an organisation must be closely interrelated to the exploration for new knowledge. They present three aspects of this management process: static, empowered and dynamic. The static aspect relates to the structure of the organisation. For example, an organisation described as 'hypertextual' may facilitate the knowledge management process. Empowerment means the need to create functions within an organisation that will be directly responsible for knowledge management such the Knowledge Manager, Knowledge Workers, Knowledge Engineers. The dynamic aspect is one where knowledge triggers change in the organisation. Knowledge has a strategic dimension - it shapes and moulds the organisation's status quo and, more importantly, its future configuration.

The knowledge creation model relies on an organisational structure similar to that of hypertext or a multilayer or multi-contextual document[11]. Hypertextual organisations combine two traditional structures: bureaucratic and project-driven. It is made up of mutually interrelated layers of a business system, project team and the knowledge base. The business system is the central layer where day-to-day routine business operations are completed. This layer is structured bureaucratically and forms a conventional hierarchical pyramid. At the top is the 'project team', in which knowledge creation processes take place as a result of interactions between groups, teams and individuals. The knowledge base layer lies at the bottom and its position harmonises with its expected function of a receptacle of all knowledge generated in the other layers and a reconfiguration engine design to produce a value added output. Knowledge is embedded in the corporate vision and culture, in technologies, external relations etc.

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[8] B. Wawrzyniak - *Od koncepcji do praktyki zarządzania wiedzą w przedsiębiorstwach* (From Concept to Practice of Managing Knowledge in an Organisation) [in] Zarządzanie wiedzą w przedsiębiorstwie [at] Materiały konferencyjne PFPK i WSPiZ (Knowledge Management in an Organisation. Conference Proceedings of the Polish Foundation for Management Promotion and the Higher School of Enterprise and Management). Warsaw 2001, p. 24.

[9] M.H. Zack - *Developing a Knowledge Strategy.* California Management Review, Vol. 40, Summer, 1999.

[10] A. Toffler, H. Toffler - *Budowanie nowej cywilizacji. Polityka trzeciej fali* (Creating a New Civilisation. The Politics of the Third Wave), Zysk S-ka, Poznań 1999, p. 17.

[11] I. Nonaka, H. Takeuchi - *The Knowledge-Creating…,* op. cit., p. 196.

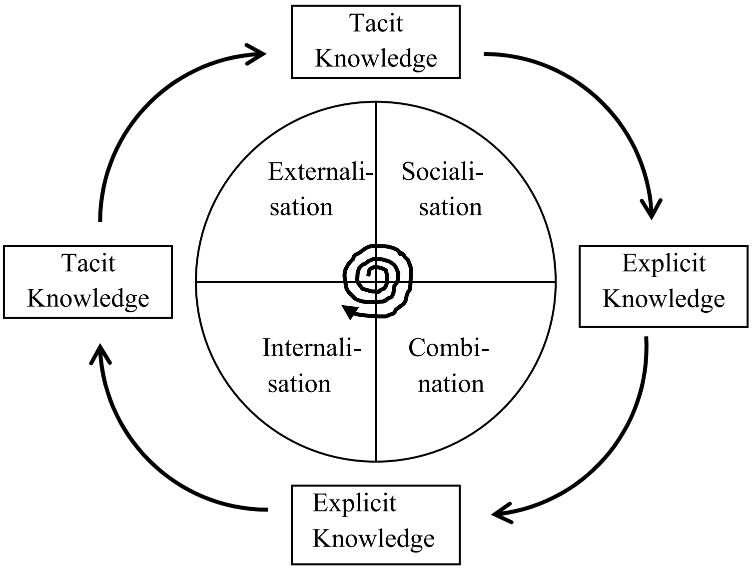

Figure 1. Knowledge spiral
(*source - based on: Kreowanie wiedzy w organizacji. Jak japońskie spółki dynamizują procesy innowacyjne [The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation] Poltext, Warsaw 2000, p. 96*)

A hypertextual organisation combines different layers with the bureaucratic organisation being complementary to the project-driven organisation.

The knowledge creation process is described by H. Takeuchi and I. Nonaka as a dynamic cycle of seamless flows of knowledge through three layers. Members of project teams come from different parts of the organisation and they create knowledge in the course of implementing a project within the guidance of the corporate vision.

Having completed their project they turn to the knowledge base layer to inject a new portion of knowledge into it. Knowledge is then reclassified and shared with the rest of the organisation. The project team go back to the business system layer to do their routine tasks until such time when they are called upon to take up a new project challenge. The ability to seamlessly and quickly switch contexts determines the organisation's capacity to create new knowledge.

An organisation must not only be responsive but also adaptive in a turbulent environment. A reactive approach and processing external information is not sufficient. Organisations themselves ought to generate new information and knowledge because this is the only way they can influence their environment and make a difference through a feedback mechanism. External knowledge is absorbed by organisations in the form of data or information and they will turn into actionable knowledge and, indeed, into new knowledge only if enriched. These cycles are iterative and this is the very central point of the model proposed by I. Nonaka and H. Takeuchi.

3 Knowledge spiral

The model of conversion of tacit knowledge into explicit knowledge refers to the dynamic aspect of knowledge management and involves the following steps[12]:

- socialisation,
- externalisation,
- combination,
- internalisation.

The development and conversion of knowledge or SECI forms a timed and logical spiral of knowledge (conf. Fig. 1).

The cycle known as SECI starts with socialisation, continues through externalisation, combination and ends with internalisation. It is at the heart of the knowledge creation process in an organisation. It forms a spiral which portrays the way knowledge is developed quantitatively and qualitatively, how it moves from the individual level to the level of the group and the entire

[12] Ibidem, pp. 85-95.

organisation. Knowledge development and creation are results of social and dynamic interactions between tacit and explicit or formal knowledge. Knowledge originates in a spiral at the interface between two dimensions; the epistemological and the ontological. The epistemological dimension manifests itself in the differentiation between the various types of knowledge and the ontological dimension relates both to the organisation but also extends beyond it and affects its environment. The epistemological dimension refers to the content, i.e. tacit versus formal knowledge and the ontology refers to the character and structure of knowledge, i.e. its origins. The four levels of knowledge should also be recognised: individual, group, organisational and inter-organisational.

The knowledge management model in a business organisation should be sensitive to the methods of knowledge creation, acquisition, maintenance, transfer and the fact it can be a product. Consequently, this means knowledge can be traded as any other goods or services. Notably, knowledge is not monosemous – it is relative and open to different individual interpretations[13]. Knowledge is dynamic and quickly becomes oblivious. Knowledge can be structured in technologies, procedures, organisational files, people competences and databases. Knowledge materialises in commercial products. In the turbulent world of today it is essential that knowledge should be seen as a factor reducing risk and uncertainty.

How should the knowledge spiral be interpreted? First, it is a unique process of knowledge conversion. Socialisation builds a 'field of interaction' which facilitates knowledge sharing among employees. Externalisation is based on a metaphor or an analogy and triggers a dialogue, a collective reflection allowing the tacit and barely transferrable knowledge to be released. The combination helps amalgamate tacit knowledge into the existing knowledge in the organisation, which is then internalised at the end of the spiral as the new knowledge is put to practical use, i.e. through 'learning by doing'. The application of knowledge created by the 'spiral' should be understood as follows: socialisation only allows a different perspective on a mode of operation or product. Externalisation directly expresses the concept deduced from socialisation which will then guide the development of a new product or services. Combination is where the concept is structured and implemented. Internalisation allows knowledge to spread widely throughout the organisation and become concurrently actionable in multiple locations.

3.1 Socialisation

Socialisation consists in observing and practicing the observed skills so that they become part of the existing knowledge. Socialisation helps tacit knowledge to expand. Members of the organisation share the 'thought models' and technical skills thus building up the corporate culture. Socialisation occurs when the tacit knowledge of an experienced employee or a 'master' transforms into the tacit knowledge of the 'student'. This is best observed in a joint involvement in a project, solving a specific problem and decision-making. Socialisation is about sharing and creating new knowledge through personal experience – it is a process of transferring knowledge from the individual level to the individual level and is strongly linked to group work theories.

The European Heritage Days are a good example of knowledge socialisation at a regional level.

European Heritage Days in Poland[14]

European Heritage Days is a joint project of the Council of Europe and the European Commission. The idea to celebrate the European Heritage Days was proposed in the Spanish region of Granada on October 3, 1985. During the second European Conference of Ministers Responsible for Culture and Heritage, Jack Lang, French Culture Minister put forward a proposal to extend the Open Days of Heritage Sites initiated in France in 1984 across the entire European continent. The proposal was enthusiastically welcomed and the Council of Europe decided to hold regular European Heritage Days. Poland has taken part in EHD since 1993 (50 countries participated in the event in 2010). The project consists of a number of initiatives implemented by local authorities, cultural institutions, com-

[13] B. Mikuła, A. Pietruszka-Ortyl, A. Potocki - *Zarządzanie przedsiębiorstwem XXI wieku. Wybrane koncepcje i metody* (Managing a Business Organisation in the 21st Century. Selected Concepts and Methods). Difin, Warsaw 2002, p. 72.

[14] The case is based on data contained in the Bachelor Diploma Paper by M. Rembacz - *Bachelor Diploma Paper: Zarządzanie projektem społeczno-edukacyjnym na przykładzie europejskich dni dziedzictwa* (Management of a Socio-Educational Project Based on the European Heritage Days Case Study), Łazarski University, 2011.

panies, civil society organisations and private individuals at the regional level.

One important element of the specific projects in individual countries is the tacit knowledge accumulated by participants. The socialisation of knowledge in the EHD projects leads to new challenges embraced by organisers. The following items were listed in 2010:

- improve public awareness of the various types of intangible heritage, rites, traditions etc.,
- direct public attention to the need for the protection, conservation and reuse of historical heritage sites,
- promote collaborative attitudes and create opportunities for joint projects within EHD,
- promote regional cultural heritage and improve the awareness of the common roots of European culture,
- strengthen intercultural dialogue,
- highlight the awareness of all EU citizens of the importance of cultural diversity,
- underline the contribution of the various culture to the heritage of European countries,
- increase the importance of education as vehicle of the transfer of knowledge on cultural diversity.

The Polish 2010 edition of EHD consisted of 1,463 events which attracted nearly 300,000 participants. Visits to cultural institutions during admission-free days accounted for only 20 per cent. The vast majority of events were EHD-specific educational projects.

The socialisation of knowledge demonstrated that the development of European Heritage Days must be preceded by an adequate ex ante evaluation, needs assessment and ex-post evaluation in each country involved. Last but not least, lessons learns must be collected both within individual countries and on project-wide scale.

3.2 Externalisation

Externalisation is a process of converting tacit into formal (explicit) knowledge. Formal knowledge is maintained in documents, manuals, patents, audio files and computer programs. Externalisation means ensuring the availability of tacit knowledge to other members of an organisation. *Externalisation is process of expressing tacit knowledge using available concepts. It is a complex process of knowledge creation in which tacit knowledge released to others in form of metaphors, analogies, concepts, hypotheses or models [...] and it is a key to knowledge creation because it delivers new ideas based on tacit knowledge*[15].

Externalisation is the heart of knowledge creation. It is here that ideas are developed based on tacit knowledge. One way of improving the level of knowledge among employees is provide training. It is much more challenging to translate the training needs to the strategic goals and objective and the efficiency of training. Let me use an example of a major retail chain which operates in Poland.

The training management function is decentralised in this retail chain, which means that operations in each country have the right to organise training based on their local needs. Managers at all levels submit their training needs which are then approved and coordinated. Training is tailor-made. The organisation has established a Vocational Development School. The leading role at the school is played by the department which has posted the strongest performance (audited) in a given period. The department manager has a role of a mentor and coach to other similar departments in the area. In addition, employees receive training to improve their skills and help externalise their knowledge. Such training if often delivered by line personnel. Trainees can learn product formulas and share their customer relationship experience. Employees feel that being invited, as rank-and-file employees, to conduct training workshops is a token of recognition and acknowledgement. The organisation has launched a forum for exchanging customer service and store work configuration ideas. Best ideas from employees are recognised and implemented in the entire chain, which has been welcomed by managers and customers alike[16].

3.3 Combination

Combination is a process leading to the expansion of formal knowledge. Explicitly, it means combining various types and forms of formal knowledge to generate new formal knowledge. Processing data to generate management information and formulating strategies are two major examples of combination. Combination is

[15] I. Nonaka, H. Takeuchi - The *Knowledge-Creating...,* op. cit., pp. 88-91.

[16] *Strategie przedsiębiorstw a zarządzanie wiedzą* (Business Strategies and Knowledge Management), (eds. J. Dąbrowski and G. Gierszewska), Publishing House of the Higher School of Enterprise and Management, Warsaw 2005, pp. 249-251.

structuring and applying formal knowledge and transferring it from the group level to the level of the entire organisation. It derives from information management theories and information technologies.

The combination of different components of explicit knowledge, after it is selected and categorised, leads to the emergence of new knowledge. New concepts may be combined with existing ones and this stimulates change. In the business context, combination may be manifested by the redefinition of existing knowledge, especially if new knowledge derived from the environment is being structured. One example of knowledge transfer in the combination mode is customer relationship management. Educations systems are examples of knowledge combination at a national level.

A complex knowledge management tool is used by KPMG. It is called KWorld and is routinely used by consultants. KWorld provides access to a wide variety of resources accumulated by others in the company, including detailed company information, existing and prospective client information, completed and ongoing projects, a knowledge library offering tools which may be helpful in projects, and internal information on the current performance of the company and individual departments[17].

Another global corporation, Citibank, has a less extensive intranet than KPMG. It is used more as a convenient support tool designed to facilitate the use of stored knowledge that a specialised and critical consultancy support tool. The intranet stores useful information which facilitates day-to-day operations such as location data on employees, current events at the bank or customer care manuals. Unlike KWorld, it is not an extensive knowledge management support tool because the bank does not offer consulting services which are strongly reliant on the unique knowledge of consultants. The Citibank internal system is called "Source" and is a typical corporate intranet solution designed to provide a 'one-stop-shop' for certain information available to staff. Source is used as a typical knowledge transfer tool by departments directly responsible for customer service. Source provides them with key information on the next steps. Monitoring and planning departments of the retail bank communicate with customer service departments via Source. Further, the system stores training resources, latest product terms and conditions and up-to-date product descriptions. Being less targeted than KWorld, Source is nonetheless considered to be perfectly aligned with the needs of a banking institution.

3.4 Internalisation

Internalisation means performing the job-related tasks according to policy, job description, management decisions. In this process, formal knowledge is converted into tacit knowledge thus leading to the growth of the tacit knowledge resource. Internalisation is building up a resource of tacit knowledge based on formal knowledge, then using the knowledge in practice and transferring it from the organisation to individual level. The creative process is driven by a continuous, dynamic and simultaneous interaction between explicit and tacit knowledge.

Internalisation involves permanently integrating knowledge units generated in the three other processes into the tacit knowledge resource, i.e. 'learning by doing'. Internalisation is a process of converting explicit knowledge into tacit knowledge by which tacit knowledge becomes a strategic resource. Once internalised, knowledge becomes part of the organisation's knowledge resource. This process can be seen as a natural consequence of the preceding processes in the knowledge spiral.

Internalisation is supported by verbalisation or documenting or orally transmitting knowledge. This makes knowledge easier to absorb and transfer to others. Internalisation yields operational and strategic knowledge, the latter being instrumental for new projects, business development and expansion. Internalisation is further strengthened by the absorption of the experience of others. The process of building up 'tacit knowledge' in the minds of individual employees is supported by verbalisation, documenting or transmitting the history of the organisation by word of mouth. If by reading and hearing about the past experiences of the organisation its members can relate to them as something meaningful such experiences may be converted into tacit knowledge. It is often enough to listen to others tell their story of a project to feel a strong urge to follow their example. Documents and files help members of the organisation who have not participated in a specific project, decision-making process or implementation to experience indirectly that other experienced directly. Internalisation is supported by learning

[17] Ibidem, p. 89.

on the job – knowledge needs to be put to a practical test in order to be internalised effectively.

External experts at AstraZeneca

J. Roth, a Swedish researcher, conducted a study on knowledge creation and sharing in the pharmaceutical company AstraZeneca[18]. The company implemented such a large number of research projects that the busy project teams could not find the time or apply any methods for sharing their knowledge with others. The Management decided to hire external experts to help the company improve its knowledge creation and sharing system.

The key responsibility of the experts was to identify processes and tools which could contribute to a more efficient transfer of knowledge in the organisation. Internal experts asked to solve this problem were highly experienced both in terms of the technical knowledge and working with teams. This was important because it was meant as a confidence builder with the team to prevent resistance to change or the 'not invented here' syndrome. There were three steps in the knowledge creation process.

Step I. Experts become established and endorsed and gather project facts. Experts interview the Project Manager to learn more about the project and identify which activities the PM believes to be important and which pose a challenge. The objective of the interview is to extract additional knowledge which will be useful in the following project phases.

Step II. Tacit knowledge is released and explicit knowledge becomes structured. A series of brainstorming sessions held with the project team members resulting in the 'knowledge on the wall' or ideas recorded on the flipchart. Following the brainstorm, another session held to structure the tacit knowledge released in the brainstorm and to disseminate it as generally available knowledge. The time between sessions allocated to team members' reflection on the developed ideas with the intention to add new ideas which were 'missed' in the brainstorm. The role of experts limited to facilitation. Team members' role limited to involvement in discussion. The output of this step was a collection of mind maps of explicit knowledge accumulated from all meetings and inputs to the final presentation. Experts rotated their roles of facilitators and record keepers.

Step III. Knowledge shared with the rest of the organisation by presenting the knowledge generated in project team meetings at an interactive seminar. Most of the seminar designed to address concerns and comments resulting from experiences other than those of the project team. The role of experts was limited to facilitation.

Summing up, J. Roth identified the following roles played by experts during the project:

- catalysts of knowledge creation - in the absence of any knowledge sharing system, they were the individuals who helped build such a system more rapidly,
- co-ordinators of knowledge sharing initiatives - they put together a process leading to a series of meetings between people from completely different departments and orchestrated knowledge sharing,
- organisation's knowledge guides - they helped create a vision of the organisation and integrated the process of knowledge creation in various different areas,
- confidence builders - they created an atmosphere of mutual trust in the project team,
- promoters of the knowledge sharing culture.

Roth emphases the need to differentiate the roles of experts and team members. The expert as an outsider had much less specialised knowledge than team members who were in fact the knowledge carriers at AstraZeneca. The main responsibility of the expert was only to help extract the tacit knowledge and streamline the process of knowledge creation. This would not, however, be successful without the knowledge of the project team members.

The approach of I. Nonaka and H. Takeuchi is comprehensive and covers not only learning and knowledge creation processes but also addresses the organisational context and environments which are conducive to knowledge acquisition and processing. The business strategy of a business organisation must specify the type of knowledge which will be critical for the organisation and where and when it will be applied. Knowledge creation in an organisation requires the involvement of people and the fundamental values of the organisation must be shared and accepted by its members. An unconventional approach to working

[18] J. Roth - *Enabling Knowledge Creation: Learning from an R&D Organization* [in] Journal of Knowledge Management, 2003, Vol. 7, No. 1, s. 32-48.

conditions, independence, recognition of creativity and out-of-the-box thinking are characteristics of many business organisations which are considered highly innovative and competitive in their sectors.

If new ideas find easily circulate in the organisation and employees have access to information extending beyond their direct operational needs there are greater chances for brand new solutions to be identified. There are three ways of achieving this: interdepartmental collaboration, competition between project teams and employee turnover.

Knowledge creation and learning are supported by flat and flexible organisation structures where individual segments are interconnected through an information network[19]. This virtually allows equal access to information and well informed units may work together with others in an emergency situation. Many companies have started implementing their knowledge management systems by deploying an intranet.

4 Conclusion

Knowledge management is a process used by an organisation to generate wealth based on its intellectual or knowledge-based internal assets: people, brands, image, employees' personal knowledge, intellectual property, and knowledge-related structures such as databanks, technologies, and internal and external relationships. While knowledge management has become a necessity today it offers no panacea for all the challenges faced by contemporary business. It is merely a perfect tool which helps improve operations in an increasingly competitive and turbulent environment[20].

Organisations which manage their knowledge are characterised by ongoing processes of customisation, customerisation and industry convergence, all of which are highly desirable in the present competitive environment. Customisation is a process by which an organisation can use its expertise to make products to individual customers' orders. It derives the knowledge directly from buyers who can communicate their expectations and product needs via a structured communication network linking them to the company. Customerisation is a combination of operational and marking customisation. The enterprise is capable of individual dialogue with each customer and responding to their feedback by adjusting its products and services and ensuring a one-to-one communication[21].

Industry convergence means the gradual disappearance of borders between sectors or even industries. For example, pharmaceutical companies have until recently been classified as part of the chemical industry. Today, they are involved in biogenic and biotechnological research to develop new drugs, cosmetics (called cosmeceuticals) or foodstuffs. The Walt Disney Company still produces films but makes profit on gifts, theme parks, store chains, hotel chains and cruise trips[22]. There are plenty of other examples. Notably, organisations that pursue such strategies have to compile knowledge from different fields, must be 'learning organisations' and have what the Japanese call the SECI Model.

In their theory of organisational learning and knowledge creation, I. Nonaka and H. Takeuchi seem to express a belief in the inherent human capacity to generate knowledge and thus change the reality. This derives from the Japanese cultural heritage: Buddhism, Confucianism and philosophical naturalism, which are the source of such characteristics of the Japanese as creativity, energy and vitality. They lead to the core of knowledge being the source of life and call for a continuous study of knowledge. This is also manifested in the martial arts practiced in Japan for centuries. Yet, the Japanese approach to knowledge management appears to wholly behavioural. It focuses on human behaviours in an organisation and on the human nature. An effective transfer, acquisition and sharing of knowledge in an organisation are possible only if interpersonal relations and intra and intergroup interactions are effective and people are united by common goals, interests and problems to be solved.

In order to address multiple management challenges, business organisations of today have to ensure an adequate understanding of knowledge and an environment for sharing knowledge via efficient communication channels, formalisation of knowledge based on available tools and informational technology. Knowledge management usually requires changes to corporate culture and the development of a knowledge culture which is expressed by organisation's the ability to learn, build its own identity, inspire confidence and foster individual and group creativity.

[19] Ibidem, p. 109.

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[21] Ph. Kotler - *Marketing*. Rebis, Poznań 2005, p. 37.

[22] Ibidem, p. 38.

Paradoxically, businesses are in need of new knowledge as it provides them with building blocks for innovation but knowledge creation is a challenging task because creativity is something that is fostered rather than managed.

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CLOUD MANUFACTURING CONCEPT AS A TOOL OF MULTIMODAL MANUFACTURING SYSTEMS INTEGRATION

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Abstract: The following article deals with a novel approach to manufacturing in the context of the increasing demand for system and process integration. This integration chiefly applies to concrete facets of manufacturing tasks which must be taken into consideration in the stage of planning and preparation for complex production processes. Those facets are primarily exemplified by order types (such as production, service and cooperative commissions etc.), production models (e.g. discrete and process modeling), product categorization based on established criteria (e.g. production technology, complexity level, used materials and extras, weight, etc.) as well as many other aspects that hold great significance in the automatization of manufacturing processes. When more advanced orders are to be realized, one of the main challenges posed by this situation is the need to accomplish multiple operations which due to their different nature, scope and scale (e.g. varied processing types: heat and plastic treating, machining etc.) have to be conducted by different contractors. In order to address those key problems and reduce the negative impact of multimodality, the author proposes a manufacturing cloud (also known as cloud manufacturing) which is a variant of a groundbreaking, yet well-established concept — cloud computing. This paper presents the chief notions of this method created specifically with integrated multimodal systems and production processes. The author also highlights key problems that should be addressed before this solution can be used in practice.

Key words: cloud computing, cloud manufacturing, internet of things, smart computing, artificial intelligence, fuzzy logic, multi-criteria selection, multimodal manufacturing systems.

1 Introduction

In the contemporary economy such concept as globalization, automatization, communication, cooperation and virtualization, are gaining significant prominence. They define the key directions of business worldwide and become manifested in information technologies which are based on the ideas of collaboration, Internet of Things and cloud computing [3]. Those notions reflect the current trends in the economic fields of goods and services. Utilizing available methods in novel and original manner within the context of economic practice becomes an imperative. One of the areas which deserves special treatment is the demand for integrating multimodal aspects of economic life.

Firstly, there are many methods which enhance the processes that occur in various manufacturing and service systems. The challenge there lies in adjusting the existing and tested solutions to new fields of economic life (e.g. different sectors of industry). For example, a task scheduling method us normally used in ordering microprocessor operations of a CPU[1] which works in many technical devices can be applied in modern workshop. Using the same CPU and drivers it is possible to schedule individual tasks and set them to different machine tools and workstations. Secondly, in case of complex goods, their production involves multiple and varied processes. Frequently, this forces a main contractor to categorize all the processes and outsource some of them to subcontractors. Seeking a capable contractor entails organization of collaboration (e.g. signing an agreement), the delay in fulfilling the commissioning, the reduction of cost-effectiveness, the partial loss of control over the order, the raise of anxiety over meeting the deadline. These setbacks are termed as multimodality of manufacturing systems. The problem of integrating such systems into coherent whole can be addressed by cloud manufacturing - whose analysis is the subject of this paper.

[1]Central Processing Unit or occasionally Central Processor Unit

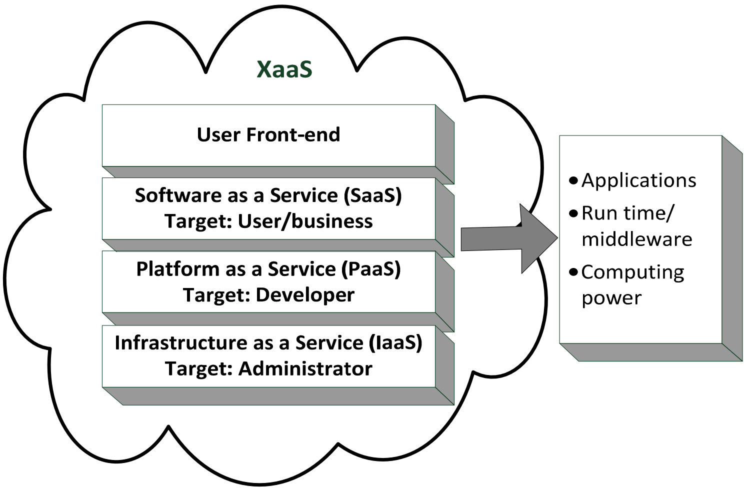

Figure 1. Cloud computing layers and services
(*source: self study on the basis of [34]*)

2 Cloud manufacturing and cloud computing

The concept of cloud manufacturing originates from cloud computing - an idea which has been in practical use for ten years. This approach enables users to access software and technological services (e.g. email, file repository, file converters, text editors) using only a working Internet connection and a web browser. One of the chief aspects of this concept is the distributed information storage. The information is not stored in a concrete, local hard drive, but in a vague, undefined, distributed environment of a network, called a cloud. Physically the files are located on specially structured drives, within so called data centers. This way of storing information and software protects it from unforeseen damages since all the data in the cloud is simultaneously copied to other locations. Normally datacenters are in great distance from each other and thus the physical destruction of one data center does not cause any loss of information. Evidently, the cloud storage model is a secure solution as far as data safety is concerned. It also offers a very convenient way of administrating data, since the administrator is freed from the obligation of preparing backup copies.

According to National Institute of Standards and Technology (NIST) [21] *cloud computing can be defined as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*. Another popular approach defines cloud computing as *a large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, virtualized, dynamically-scalable, managed computing power, storage, platforms, and services are delivered on demand to external customer over the Internet* [8]. The above said definitions reflect key features of cloud computing: network collaboration, scalability, flexibility, versatility and straightforward management. All of these factors make cloud computing technologies easy to implement in various walks of economic life. The concept of cloud computing assumes that the interaction between a service provider and a user is based on services. Those services, depending on their character, can be divided into three categories: SaaS (Software as a Service), PaaS (Platform as a Service) and IaaS (Infrastructure as a Service) [31]. Generally, all the services offered through cloud computing model can be defined as "everything as a service" (XaaS) (see Fig. 1). These terms together form a multilayered cloud computing system. The infrastructure layer (IaaS) standardizes a number of processes realized in the cloud: data processing, storage, networking etc. In this model a cloud provider enables his clients (users) to install and launch an operating systems and utility software. PaaSis the middle layer in the hierarchy.

It offers tools necessary to build one's own software as well as environments which allow it to be tested, implemented, hosted and developed further. The highest layer include computing hierarchical structure is SaaS - this model enables users to take advantage of a ready, compiled utility application.

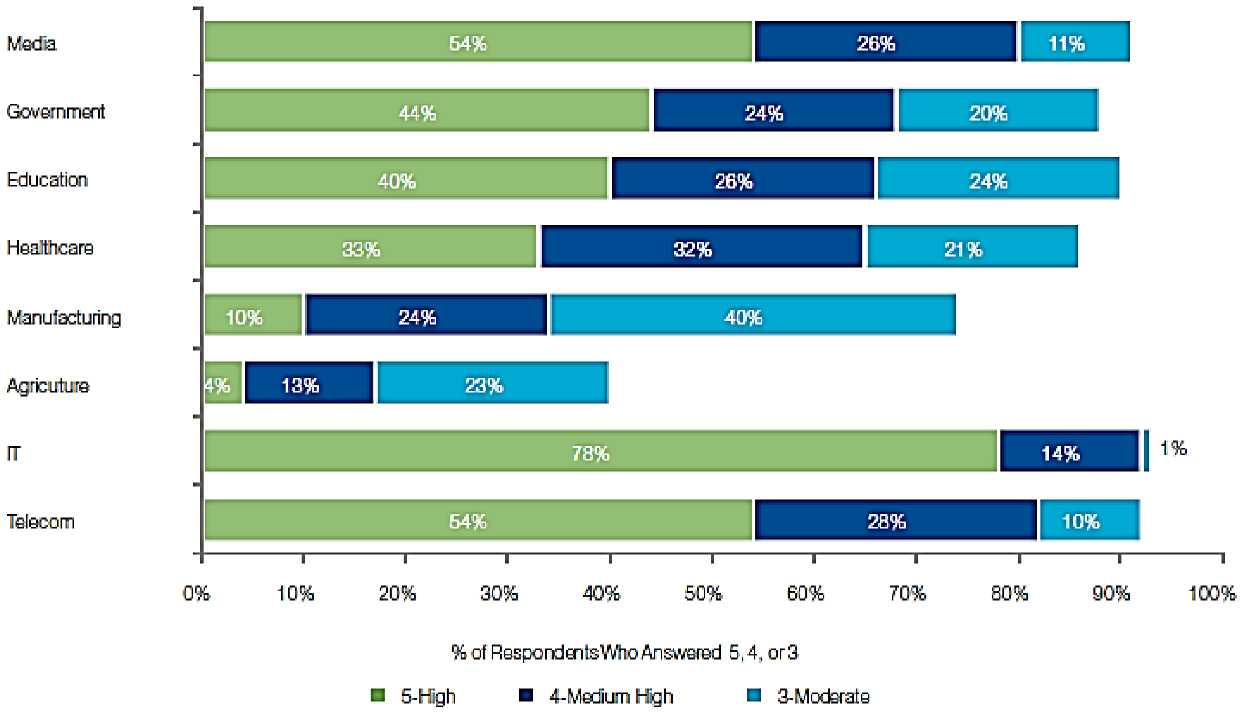

Figure 2. Multimodal industries which are most likely to be impacted by cloud computing (*source [33]*)

3 Multimodal industrial integration

The value of each method is determined on account of certain evaluation criteria. The concept of cloud computing is ranked highly in the field of Information and Communication Technology (ICT) due to a number of advantages which directly influence the quality and the way of performing information processing operations. This idea itself, however, is universal enough to be applied to other facets of social and economic life (see Fig. 2). The only problem this raises is the need to create discrete informational and organizational models to apply for every field of expertise. Precisely due to varied models cloud computing enjoys different levels of applicability in a number of fields of life.

The current technological level of IT does not permit creating a universal software based upon the cloud platform whose versatility would be sufficient to use it interdisciplinary. However, the multimodality of the fields of use caused cloud computing to be adapted in a number of social and business spheres, e.g. media, education, healthcare, manufacturing, telecommunication etc. (see Fig. 2). The challenge of adjusting cloud computing to the manufacturing challenges requires a new, original service model that would take into account many precise assumptions and which would allow the business to tackle many problems specific to concrete lines of industry [34]. Bearing this in mind, cloud manufacturing can be seen as an integrated set of methods which deal with the realization of production process and production services. The concept of cloud manufacturing involves the use of cloud infrastructure in each phase of the production process. (see Fig. 3). Cloud manufacturing is often mistakenly linked to the notions of networked manufacturing, Internet-based manufacturing or distributed manufacturing. These three concepts assume the integration of distributed resources in order to perform a single production task ([20], [26]), whereas the idea of cloud computing permits the realization of multiple tasks of this kind. According to the principles of cloud manufacturing distributed production resources can be integrated and integrated production resources distributed between a number of businesses. Thus, analogically to the concept of cloud computing, cloud manufacturing can be defined as *a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing resources (e.g., manufacturing software tools, manufacturing equipment, and manufacturing capabilities) which can be rapidly provisioned and released with minimal management effort or service provider interaction* [34].

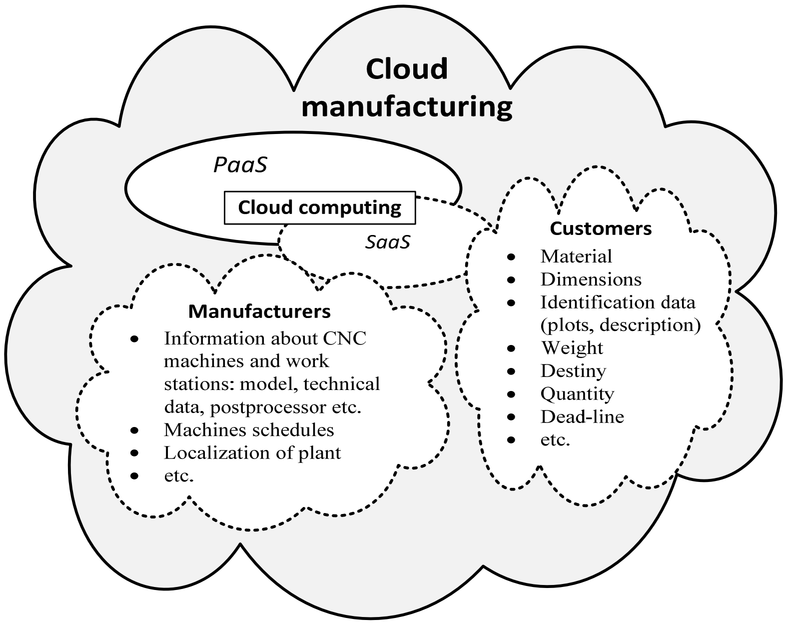

Figure 3. The concept of cloud manufacturing
(*source: self-study*)

The practical realization of the presented concept requires an enterprise to create a web portal which works as a highly automated storage of production orders and production capabilities of each of the parties involved in the manufacturing process. This portal could enable the prospective customers to register and fully describe a desired item. The portal would also register businesses capable of utilizing particular CNC machine stocks.

Having CNC machine tools is critical, since a machine tool typically has access to LAN/WAN networks. Owing to this approach, the web portal that implements cloud manufacturing could have real-time access to all the necessary information directly from all manufacturing environments.

Furthermore this portal could give access to MRP/ERP class systems as a service [25], whose main task would be to plan all the jobs for each machine tool registered in the cloud in advance. This step is necessary in order to properly prepare the automatic realization of a given tasks.

4 Architecture of cloud manufacturing system

The basic structure of the highlighted cloud manufacturing model comprises two sides (manufacturer's and customer's) and six layers. The manufacturer's side layers are composed of: application layer, global service layer, virtual service layer and manufacturing resource layer. On the other hand the customer's side layers are: manufacturer selection layer and order description layer (see Fig. 4). The application layer in user domain permits producers (user-manufacturers) to create their own software components characterized by modularity, mobility and pluggability (the readiness to attach the given component to an entire system, increasing its functionality).

The application layer is implemented according to SaaS model [30] as a web run-time environment, which permits the users to build new computer software as well as allows its testing (simulation) before its integration with the system. Once the new components have been examined they can be incorporated into the system (in the global service layer) as run-time modules. The provider domain contains two layers, which are directly associated with a production business. The manufacturing resource layer comprises the software used to stock-take the resources available to concrete production enterprises.

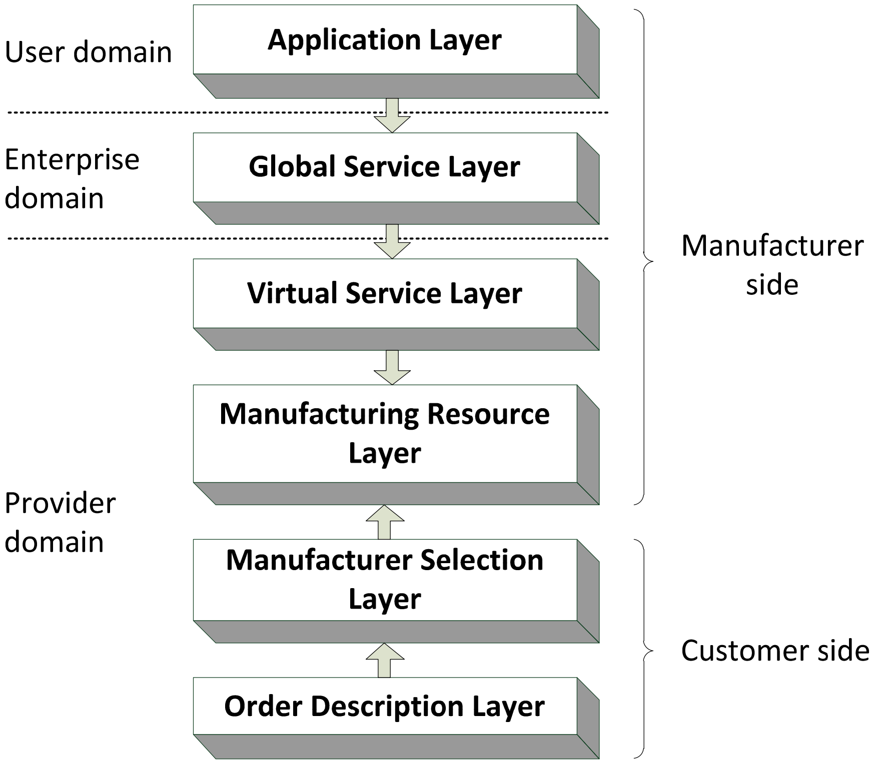

Figure 4. Layered framework of cloud manufacturing system
(*source: self-study on the basis of [34]*)

The most critical are the information on the ready-to-use CNC machine tools and the current state of orders from the given field. Manufacturing service layer is composed of tools that identify production resources, permit their virtualization and relocate them in a network as cloud manufacturing services. It needs to be stressed that all of these tasks are much more difficult to implement in cloud manufacturing model than in cloud computing. The informational tools in the provider domain have other, significant uses. One of the basic functionalities of cloud manufacturing is matching the right providers with concrete production orders, so apart from manufacturer's side, a cloud manufacturing platform should also account for the client's side. For that reason, two layers of provider domain in this platform work also for a client.

The first one – Order Description Layer – enables users to give a detailed description required for the producers to properly fulfill the task. The order is taken through an interactive form, where the questions given depend on the answers provided beforehand. This form constitutes a method of initiating a formalized dialogue by the system with the client. The goal of the dialogue is to determine the subject of an order. The data collected in this way should help to identify the construction of the item and required technology as well as determine expected limitations, customer's special requirements and other information which would impact the appraisal of the order. Moreover, a user should be able to attach CAD or CAM file with additional details. On account of the high level of complexity involved in identifying the problem a manufacturer selection layer was created. This layer consists of software responsible for determining technological operations required for a given order, selecting the correct providers, and if necessary supplying a technological path (the order of operations and providers in a technological chain).

5 Deployment problems

This chapters deals with the most common problems that must be addressed before the concept of cloud manufacturing can be implemented. Furthermore, it gives a viable solution to one of the more difficult challenges – the multi-criteria selection of production service providers. The solution consist of two steps. The first phase involves the system selecting all capable machine tools, disregarding their physical location. The second phase is the client's choice of a production or a group of production providers for the manufacturing task.

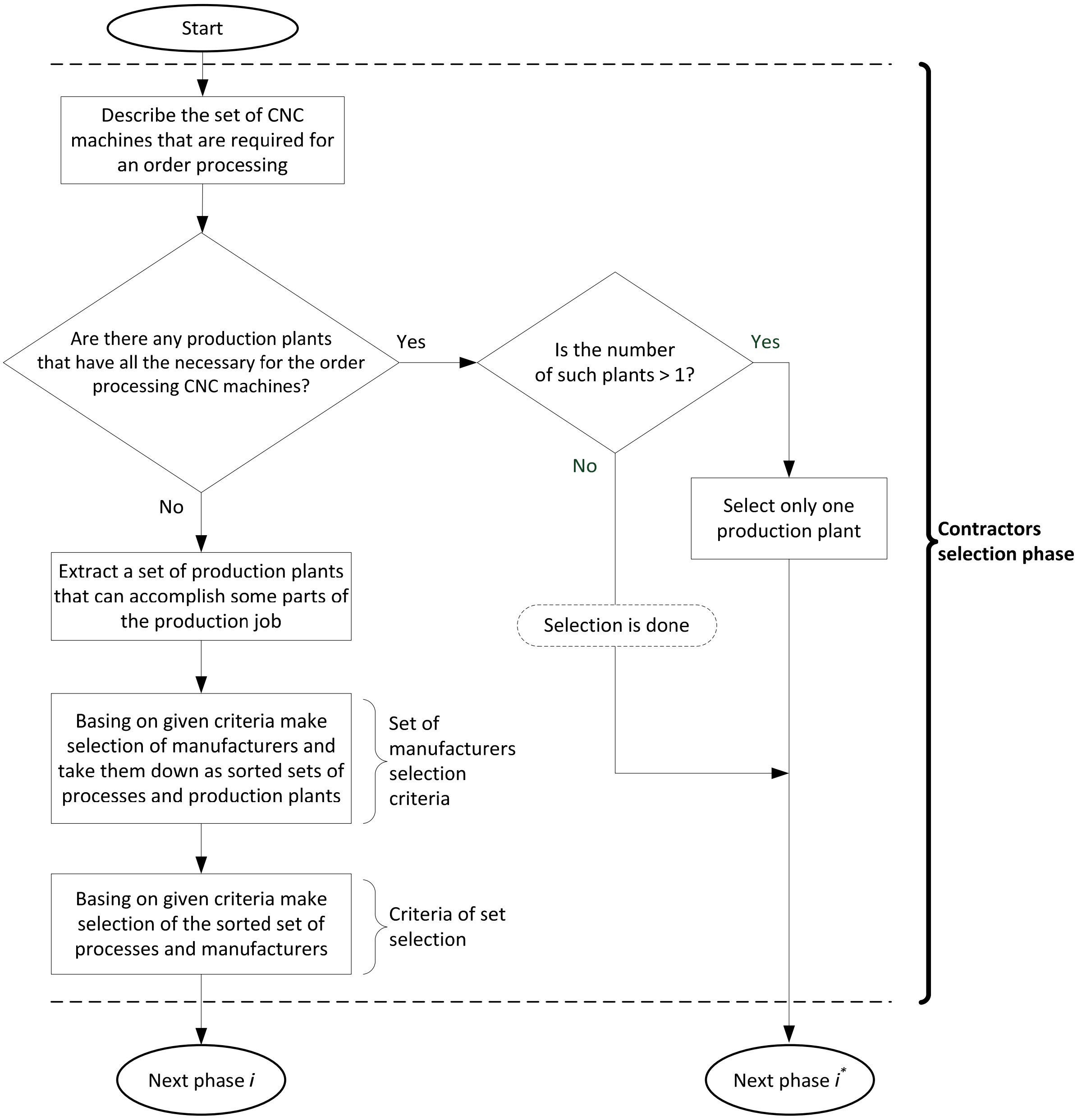

Figure 5. The algorithm for manufacturer selection in cloud manufacturing model (*source: self-study*)

5.1 Key requirements of cloud manufacturing systems

The cloud manufacturing presents a number of problematic issues, which require adequate solutions. Those issues include:

- preparing an interactive form that can be used to define manufacturing commissions,
- preparing the mechanism that enables selection of a qualified provider for a defined manufacturing order,
- preparing interfaces with a real-time access to manufacturing resources of production facilities (the potential contractors),
- preparing MRP/ERP class system that could provide services in SaaS model,
- adjusting the web portals to different lines of industry,
- data security and backup as well as adapting to international law in case of international character of the project (e.g. when the client and the provider are based in different countries), etc.

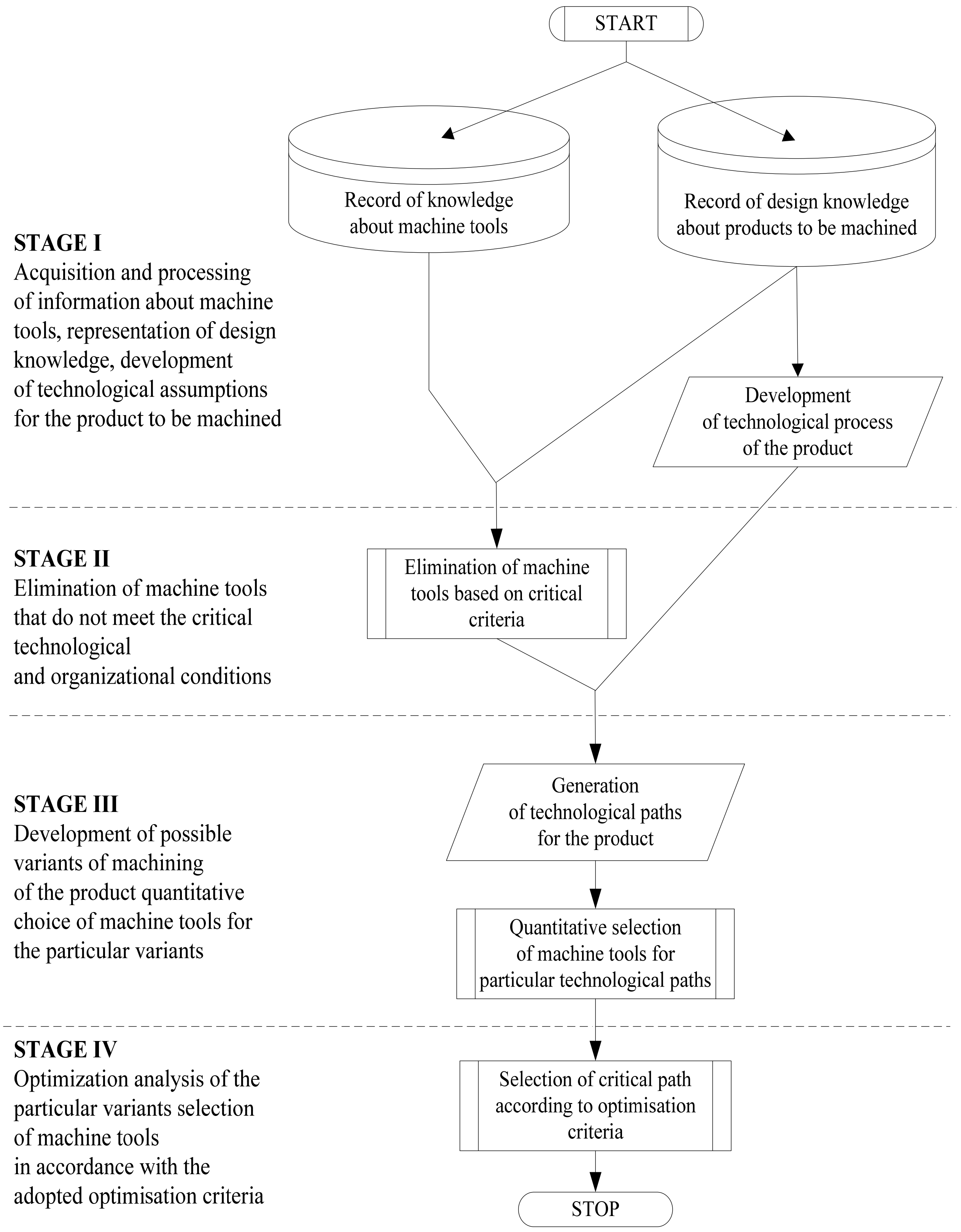

Figure 6. Algorithm of machine tool selection
(*source: self-study on the basis of [9]*)

5.2 Selection of manufacturers

The chief argument that supports the efficacy of cloud manufacturing is the high level of automatization which characterizes many processes on the line client-provider during the realization of business transactions. The most serious issue is finding an effective algorithm which could efficiently match manufacturing providers with specific production tasks. Complex orders may involve many contractors that are to perform multiple stages of a manufacturing process. This requires from them to be identified by the system and selected in an appropriate order determined by a technological route (see Fig. 5). Provider identification involves determining what kind of manufacturing tools (mainly CNC machine tools) are required by the order. Next, user should select particular machine tool from among all of the machines registered in a manufacturing cloud. During this selection many criteria are taken into consideration. First and foremost, the selection should account for critical criteria-to rule out all machine tools which are incapable of accomplishing any of the identified technological operations. The second group of criteria should focus on minimizing the manufacturing time and cost. One significant aspect which factors in this choice is the close proximity of the machine tools returned by the search. An ideal solution would be to find a single enterprise with extensive enough assets to perform all the necessary technological operations on-site. If it turned out to be impossible, the algorithm should group the prospective contractors so that the number of the parties involved in the process would be minimal. As cloud manufacturing platform develops there could appear new sets of more sophisticated criteria such as the cost and time of transportation of the produced elements, work-time schedule of individual enterprises, the estimated experience of the contractor in realizing similar projects, etc.

5.3 Algorithm of machine tool selection

As mentioned before a contractor search may return results with many different parties involved at different stages of order realization which will require cooperation with one or more enterprises. The number of the parties involved in the project depends on the kinds of machine tools needed to complete it. In case of versatile CNC centers, many operations can be finalized on-site, which reduces the number of required machines in a technological path. A modified algorithm normally used in machine tools working in a flexible manufacturing systems can be used as a basis for machine selection. (see Fig. 6) ([9], [10], [11] and [12]).

This algorithm consists of four stages. The first stage comes down to gathering and processing the data on machine tools, representation and form of construction knowledge and technological plan of a constructed item. The data on available machine tools are constantly monitored owing to the abovementioned MT Connect standard. The representation of knowledge ought to fulfill two essential objectives:

- formalization of the parts required in processing in the form on input data for a data management system. This allows the system to match the construction characteristics of the parts with the parameters of the machine tools.
- efficient data processing, which automatizes the process of machine tool selection, matching them with appropriate goods which can be create in the cloud manufacturing environment.

	x_1	x_2	x_3	x_4	x_5	…	x_m
δ_1	0	0	1	0	0		0
δ_2	1	0	1	1	1		1
δ_3	0	1	0	1	1		0
δ_4	0	1	1	0	0		1
δ_5	0	0	1	0	0		0
δ_6	1	0	0	1	0		0
δ_7	1	1	0	1	0		1
δ_8	1	0	0	1	0		1
δ_9	0	1	0	0	1		0
δ_{10}	0	1	1	0	1		1
δ_{11}	0	1	0	0	1		0
δ_{12}	0	1	0	0	1		1
δ_z	1	0	1	1	0		1

where:
$x_1, x_2, \ldots, x_m$ are the machine tools from set X,
$\delta_1 \ldots \delta_z$ – successive cuts during manufacturing process,
1 – "one" in the matrix means possibility of machining specified cut on the specified machine tool,
0 – "zero" means such possibility does not exist.

Figure 7. Matrix of technological capabilities in relation to the particular product or part (*source: self-study on the basis of [12]*)

The second stage involves elimination of all machine tools that fail to fulfill technical and organizational requirements. Examples of these critical criteria include: the ability to use numerical control, the maximal strain of the machine's table, maximal dimension of the item to be processed by the machine, the maximal dimensions of the hooks and grapples needed to attach the item, etc. The result of phase two can be translate into adjacency matrix of machine tools and operations (see Fig. 7). This matrix should contain the information about all available machine tools and all the operations needed do create a desired item. If there are no 0 values in a given column of the matrix, it means that all operations can be completed using a single machine tool. A column filled with zero values signifies that the picked machine tool cannot complete any of desired technological operations with respect to the given manufacturing task. Another extreme example: if there are only 0 values in the given row, it means that the set of machine tools has insufficient capability to complete the manufacturing order.

The third stage is preparing all the possible processing variants of the item and selecting the cost-effective number of machine tools for each possibility.

The last phase - stage four - entails optimizing each of the variants and matching machine tools with predefined optimization criteria. The procedure of choosing an appropriate technological path has been presented on a straightforward example. The columns of a [3x3] capacity requirements matrix A_{mz} contain information about available tools, and its rows the required technological operations.

$$A_{mz} = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

The value 1 signifies that a given machine tool can carry out the required process; 0 means the opposite. The available technological routes go down the columns in the A_{mz} matrix, along all 1 digits in different columns. Each 0 in a column means that the machine tool needs to be changed which may also entail changing the service provider. Thus the most desirable route is the one with the least number of such changes. In the presented example there are six possible technological routes (see Table 1).

Table 1. Developing technological paths
(source:self-study on the basis of [12])

Solution No.	Technological paths	No. of changes
P_1	1-2-1	2
P_2	**1-2-2**	①
P_3	1-2-3	2
P_4	3-2-1	2
P_5	**3-2-2**	①
P_6	3-2-3	2

Having analyzed all the available routes and a number of changes in each one it can be concluded that there are two equally efficient solutions: In P_2 and P_5 routes there is only one change. The further stages of selection which lead to the choice of a single solution can be based on other algorithms.

For example, one can assign weights to particular characteristics of a machine or an manufacturing enterprise which owns a number of them. Owing to this method each alternative technological route will be additionally marked with a parameter, which reflects the summary value of each path. As a result it is easy to determine the efficiency of each solution which can help identify the best service providers

5.4 Fuzzy inference system of manufacturers selection

Due to a significant progress in information technologies it is relatively easy (i.e. fast and cheap) to build a decision making system using the instruments based on artificial intelligence. The example that will be discussed herein is a fuzzy inference system (FIS) whose objective is to assess potential service providers (contractors). In contrast with previously highlighted method of matching tasks with appropriate machine tools, the discussed FIS controller would be useful at the second stage of the selection. The first stage determined a set of technological paths which constituted balanced solution. The next phase of the procedure results in the final solution based on the criteria established in respect to an enterprise, as opposed to separate machine tools.

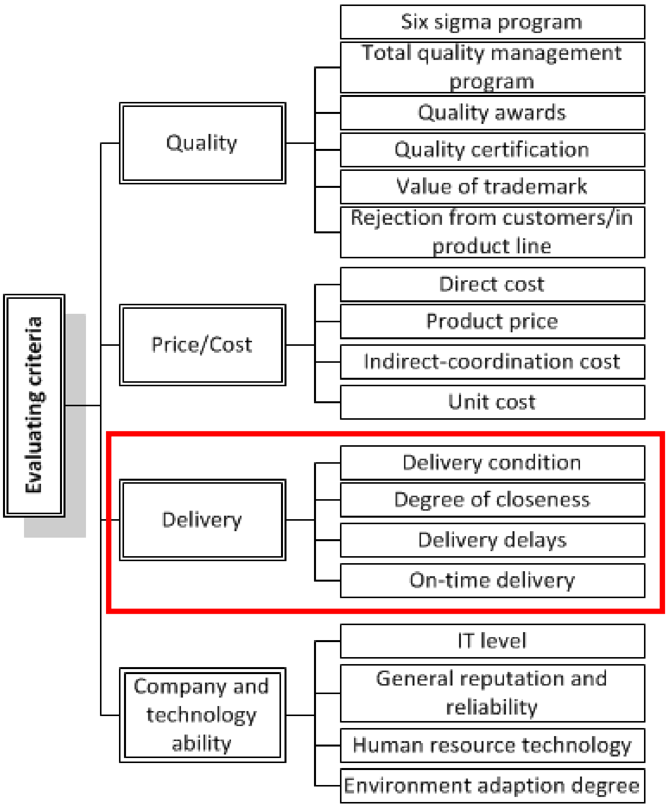

Figure 8. Hierarchy of evaluating criteria and sub-criteria to fuzzy-based computing process (*source: self-study on the basis of [19]*)

The key advantage of fuzzy logic is the fact that it can be used to describe any phenomena with qualitative or quantitative variables. Quantitative variables are objective, easy to measure and credible. In contrast, qualitative variables are frequently subjective as they depend on the opinions of individual persons who have judged them. For this reason qualitative variables have linguistic form (descriptions). A fuzzy set is an area where the level of membership with the set is described by a real number from the range between 0 and 1. A fuzzy set is defined by a membership function, which associates objects form the given discipline with a numerical value that describes their level of membership with the set. The membership function $\tilde{A}$ is defined as $\mu_{\tilde{A}}$, while the value of membership is defined by $\mu_{\tilde{A}}(x)$. A linguistic variable reflects qualitative information with a description or a membership function - in the latter case it carries quantitative meaning. The fuzzy set $\tilde{A}$ in X is determined by a membership function, which is defined as $\mu_{\tilde{A}}(x): x \in X \rightarrow [0,1]$, where X is a domain space. Depending on the context of x, the membership function may be interpreted differently. For example, the membership value of delivery x, which belongs to a fuzzy set of preferences can be subjectively estimated from client's satisfaction level - the person who receives the parcel. The membership function determines the intensity of preferences of the person who assesses the benefit from the received shipment. According to the fuzzy set theory it is possible to use constant values of the membership function from the (0,1) interval as illustrated in formula 1 [22].

$$\mu_{\tilde{A}}(x) = \begin{cases} 1 \quad \text{iif} \quad x \in \tilde{A} \\ 0 \quad \text{iif} \quad x \notin \tilde{A} \\ p \quad 0 < p < 1 \\ \text{if x partially belongs to } \tilde{A} \end{cases} \qquad (1)$$

In the fuzzy set theory all equations are formed with a membership function. Taking into account the value of an input parameter, the output of an membership function returns "the degree of truth". All of the elements in a fuzzy set present a certain degree of membership which is determined by the membership function. As we remember the membership range is an interval between 0 and 1, where 0 signifies that the element does not belong to the fuzzy set, 1 means full membership and any other value means partial membership [37]. The fuzzy controller used in this work has been based upon Mamdani's model.

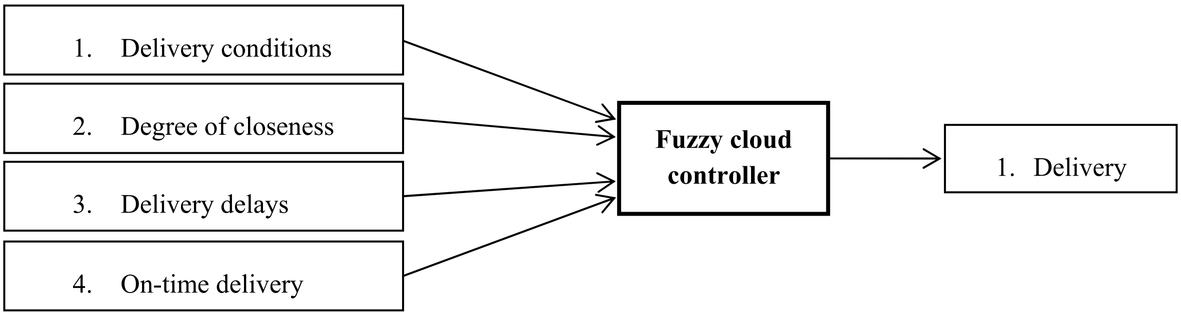

Figure 9. Fuzzy controller: inputs and output
(*source: self-study*)

The controller has a set of inputs, which correspond to the criteria that define the selection of a contractor. In the test scenario a number of chief criteria defining the selection of the best provider were identified:

- Quality - the level of how well made an order item is,
- Price/Cost - the criterion that accounts for the overall price,
- Delivery - the criterion that accounts for the issues connected with the delivery of a product,
- Company and technological capacity - this criterion accounts for technological capabilities of the enterprise and its prestige.

All of those criteria are defined as variables with the values from the interval of (0,1) (see Fig. 8). The numerical value of each of the criteria generates a separate fuzzy logic module. As a result we determine the vector of numerical values which correspond to individual evaluation criteria of the manufacturing company. Those values can be totaled up to receive the figure which reflects the level of attractiveness of particular business. In order to link the evaluation indicator to the actual condition of the given enterprise, each criterion can have weights ascribed to them. This will diversify the influence of criteria on the final score.

It should be noted that owing to fuzzy logic (also known as soft computing method) it is possible to take into consideration not only the quantitative criteria such as price, but also qualitative criteria which are difficult to measure. A fuzzy logic controller which has been build in accordance with the above said method is characterized by modular construction where every module is responsible for identifying the value of a separate criterion. For example, in this hypothetical scenario the quality of delivery service is measured by Delivery criterion. As established before, the evaluation (score) generated in this criterion takes the form of a number from (0,1) interval, where 0 means lack of capacity for delivery and 1 signifies full delivery capacity.

Delivery criterion was conditioned by four fuzzy variables: Delivery conditions, Degree of closeness, Delivery delays, On time delivery. All of these fuzzy variables are also linguistic variables and are the subcriteria of the Delivery parameter (see Fig. 9).

It can be clearly observed that these four variables are qualitative in character. Usually this presents a considerable challenge, as those parameters have to be converted to a scalar form. In case of a fuzzy controller the first phase of data processing involves "fuzzification" of variable values which are given as numbers from a pre-determined scale. In this example the scale of the input variables corresponds to the scale of output variables - all values are real numbers set between (0,1).

All the four input variables are "fuzzied" with the same membership function in a triangle wave, according to formula 2.

$$\mu_{\tilde{A}}(x, a, b, c) = \max\left(\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right) \quad (1)$$

where: a, b, c - are the parameters that determine the exact location of the three angles of the $x \in R, 0 \leq x \leq 1$triangle.

All of the membership functions of the Delivery input variable take the form of a triangle wave and differ only in a, b and c parameters. The plot of the membership function correspond to five linguistic variables which determine the degree of membership of the output variable for the given fuzzy set. The shape of each progress of all membership functions for every input variable depends on a, b and c parameters, which has been presented in Table 2. The inserted values correspond to the function graph in Fig. 10 - 14.

Table 2. The parameters associated with the triangular membership functions of Delivery
(source: self study)

1. Delivery conditions (input)			
Membership functions	Parameters		
	a	b	c
Very bad	0	0	0.3
Bad	0,1	0,3	0,5
Fair	0,3	0,5	0,7
Good	0,5	0,7	0,9
Very good	0,7	1	1

2. Degree of closeness (input)			
Membership functions	Parameters		
	a	b	c
Very far	-0.25	0	0.25
Far	0	0,25	0,5
Average	0,25	0,5	0,75
Close	0,5	0,75	1
Very close	0,75	1	1,25

3. Delivery delays (input)			
Membership functions	Parameters		
	a	b	c
Very big	-0,25	0	0,25
Big	0	0,25	0,5
Average	0,25	0,5	0,75
Small	0,5	0,75	1
Very small	0,75	1	1,25

4. On-time delivery (input)			
Membership functions	Parameters		
	a	b	c
Very bad	-0,25	0	0,25
Bad	0	0,25	0,5
Average	0,25	0,5	0,75
Good	0,5	0,75	1
Very good	0,75	1	1,25

5. Delivery(output)			
Membership functions	Parameters		
	a	b	c
Very poor	-0,25	0	0,25
Poor	0	0,25	0,5
Fair	0,25	0,5	0,75
Good	0,5	0,75	1
Excellent	0,75	1	1,25

As a consequence each of the four input variables is being "fuzzied" with five adequately matched membership functions. In this case a triangular wave was used, but such parameters as: the values of membership functions, their type and their progress should be selected by an experienced designer. The designer should master the techniques of fuzzy logic as well as possess the practical knowledge from the discipline that factors in the issue in question. There are certain standards and operation schemes, which have been used practically and can serve as a general behavior model in designing Fuzzy Interface Systems. Nonetheless, due to the lack of firm and unequivocal methodical rules each instance of constructing a system that is based on fuzzy logic ought to be considered individually.

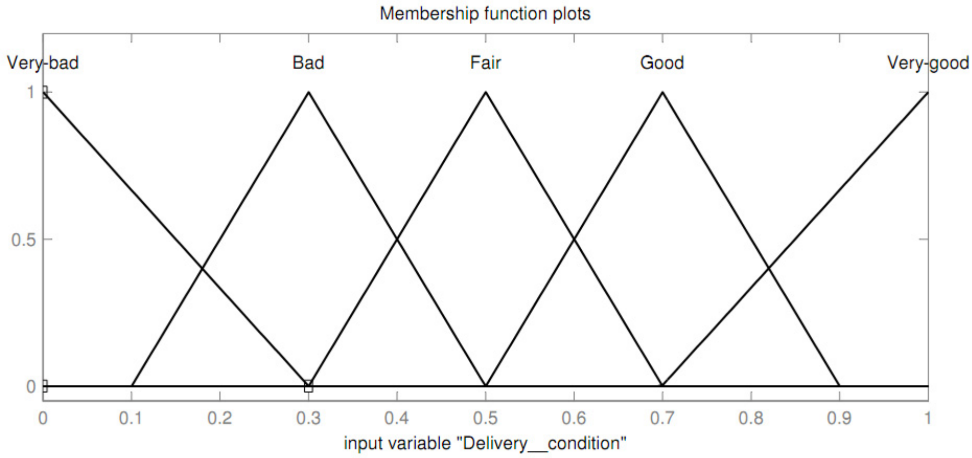

Figure 10. The linguistic terms of *Delivery condition* fuzzy input variable and membership function plots (*source: self-study*)

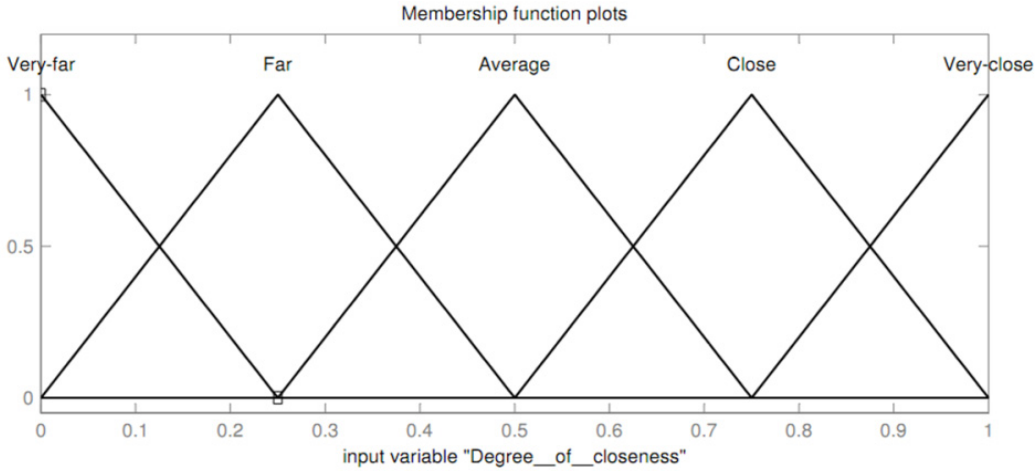

Figure 11. The linguistic terms of *Degree of closeness* fuzzy input variable and membership function plots (*source: self-study*)

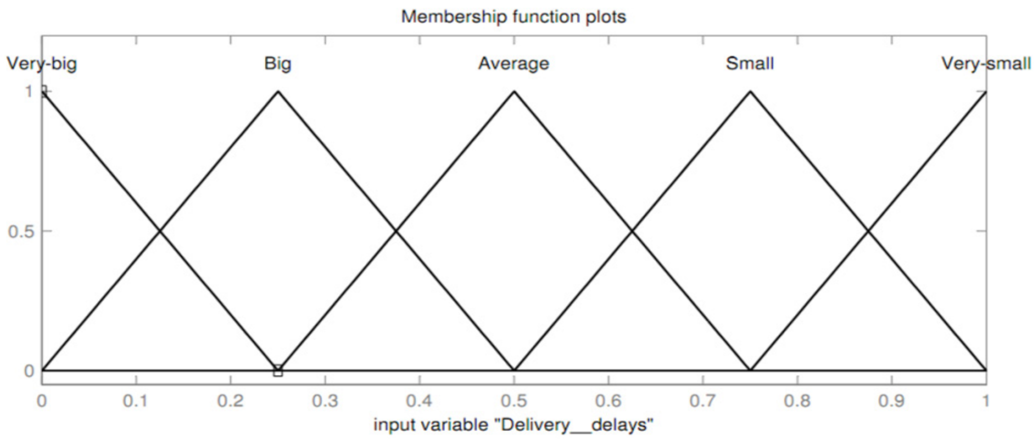

Figure 12. The linguistic terms of *Delivery delays* fuzzy input variable and membership function plots (*source: self-study*)

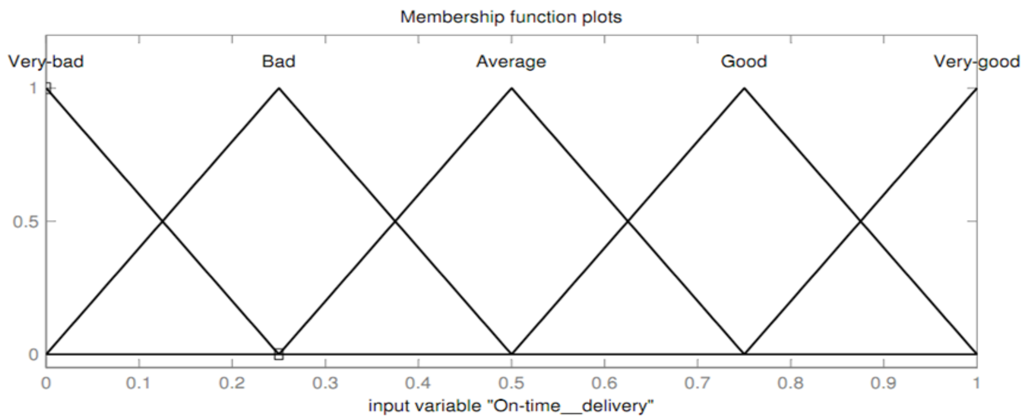

Figure 13. The linguistic terms of On-time fuzzy input variable delivery and membership function plots (*source: self-study*)

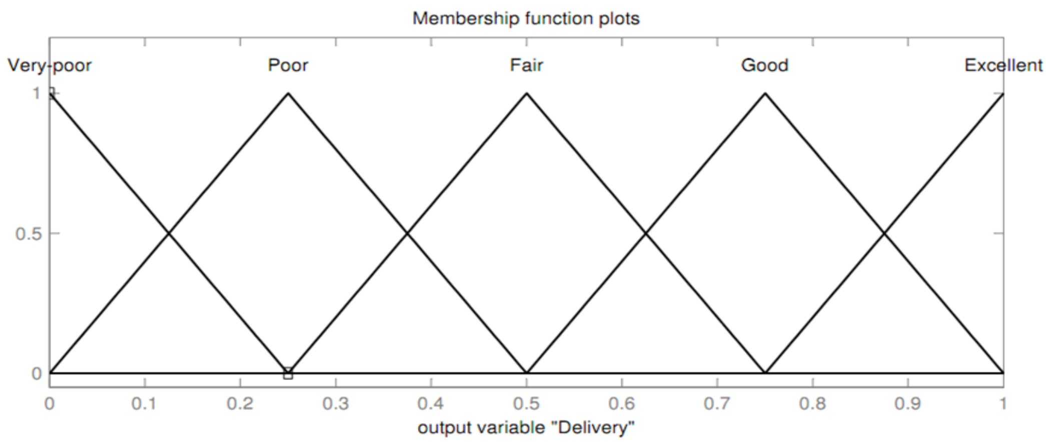

Figure 14. The linguistic terms of Delivery and membership fuzzy output variable function plots *(source: self-study)*

There are six fuzzification rules which were used in this controller:

1) if (Delivery_condition is Very-bad)
   or (Degree_of_closeness is Very-far)
   or (Delivery_delays is Very-big)
   or (On-time_delivery is Very-bad)
   then (Delivery is Very-poor),
2) if (Delivery_condition is Bad)
   or (Degree_of_closeness is Far)
   or (Delivery_delays is Big)
   then (Delivery is Poor),
3) if (On-time delivery is Bad)
   then (Delivery is Poor).
4) if (Delivery delays is Average)
   or (On-time delivery is Average)
   then (Delivery is Fair),
5) if (Delivery_condition is Good)
   or (Degree_of_closeness is Close)
   or (Delivery_delays is Small)
   or (On-time_delivery is Good)
   then (Delivery is Good),
6) if (Delivery_condition is Very-good)
   or (Degree_of_closeness is Very-close)
   or (Delivery_delays is Very-small)
   or (On-time_delivery is Very-good)
   then (Defivery is Excellent).

This controller possesses an additional functionality - it can assign different weights to various fuzzification rules. However, due to the theoretical character of the problem it has been decided that all rules are equivocal.

Figure 15. Fuzzy reasoning realized by FIS controller
(*source: self-study*)

The theoretical performance of the controller is illustrated in Fig.15. In the presented scenario, each of the five variables takes different values. The first four columns in Fig. 15 correspond to the four input variables, while the fifth one stands for an output variable. In this case the fuzzy input variables take their values from Table 3.

Table 3. The values of fuzzy input variables
(*source: own work*)

Fuzzy input variable	Value
Delivery conditions	0,206
Degree of closeness	0,879
Delivery delays	0,866
On-timedelivery	0,912

The first six rows in Figure 15 reflect six rules of fuzzification, whilst the lower right corner presents the process of defuzzification. The graphs in the right column depict the final results of the six rules of fuzzification being applied on the variables. The next stage entails result aggregation for each of the rules which is used to draw an aggregate graph. This graph portrays a substantial form, which constitutes a starting point for the next stage of fuzzy logic control - defuzzification. This process is accomplished with a centroid method, which progresses according to formula 3.

$$y = \frac{\int \mu_{\tilde{A}}(x)xdx}{\int \mu_{\tilde{A}}(x)dx} \quad (2)$$

Fig. 16 illustrates defuzzification in this method. It can be observed that determining the coordinates of the center of mass of the form is not required, since the final result is read from the horizontalaxis of the figure. In this case the final result equals 0,537.

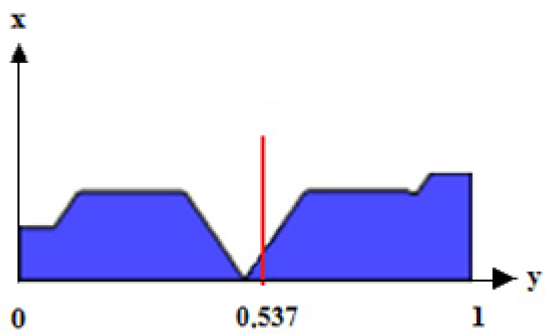

Figure 16. Defuzzification with centroid method
(*source: self-study*)

Fig.17 presents the surface of available solutions, which depicts the values that the output Delivery variable can take depending on the two selected input parameters: Degree_of_closeness and Delivery_conditions. As can be seen the surface presented in the shape is irregular which signifies that the used inference mechanism was very complex. Apart from that it should be noted that Fig. 17 presents merely a fragment of a bigger issue, as the fuzzy controller uses four variables in the evaluation of the quality of the delivery, not just two as in this case. This figure illustrates the fundamental advantage of scalable inference systems based upon fuzzy logic - their efficiency.

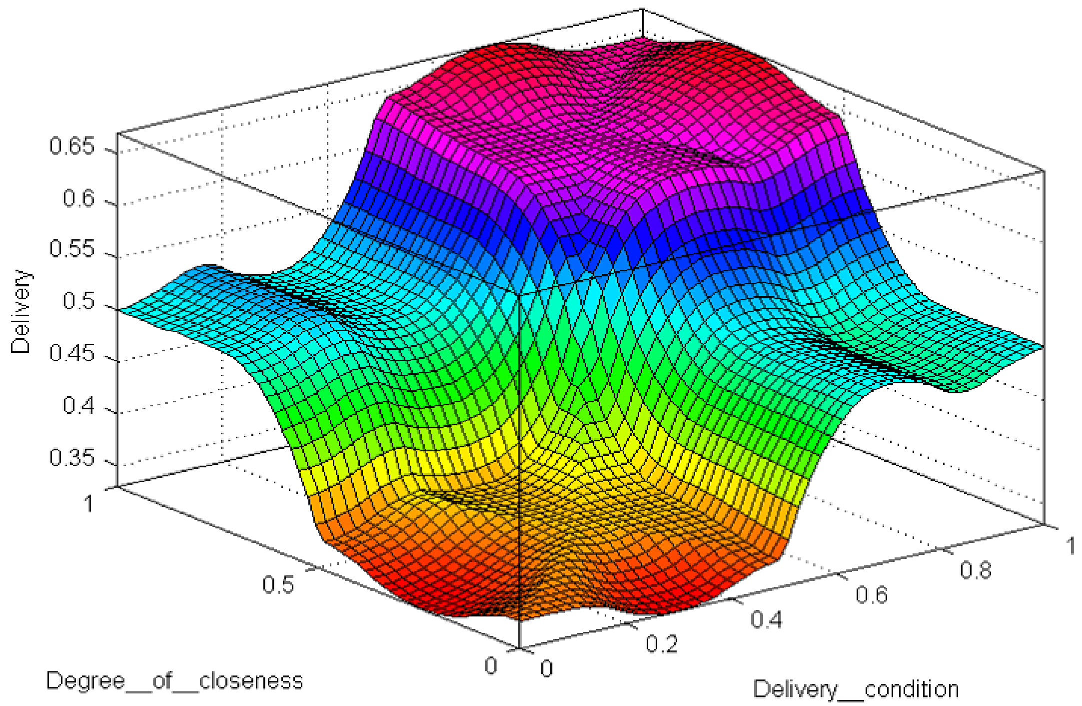

Figure 17. The linguistic terms of fuzzy variable Delivery condition and membership functions plots (*source: self-study*)

The progress in ICT fields permits a designer to construct a controller with relatively low amount of work using just standard simulation software. This controller can comprise plenty of subtle elements, which reflect even the most mundane aspects of selecting a contractor.

Apart from the fuzzy logic techniques, the problem of multicriterional selection can be addressed using other methods that depend on information technologies, such as: Data Envelopment Analysis (DEA), Analytic Hierarchy Process (AHP) [1], Decision Support System (DSS) based on the AHP model [15], Cluster Analysis (CA) [2], Case Based Reasoning (CBR) [6] etc.

5.5 Identification of resources and their monitoring

The method of identifying and monitoring the resources distributed in a cloud environment in real time is another important problem that needs to be dealt with at the stage of designing a cloud manufacturing platform. In order that the process can be performed it is necessary to link all the monitored assets of the enterprise (e.g. CNC machine tools) to a LAN/WAN network. This condition is not difficult to fulfill, especially if the company has CNC class devices which are less than ten years old. This type of devices is usually fitted with RJ-45 interfaces or WiFi LAN adapters that can be used to connect them to a network. The method of communication of CNC tool with the entire system is another important question. The communication should be founded on the software that can read the data from CNC machine tools operator which use different control systems (e.g. Sinumerik, Heidenhain, Fanuc etc.) and transform them to universal format. To this end MTConnect standard, which is a trusted solution based on an open data transfer protocol, can be used [5].

The principal advantage of MTConnect is the capacity to connect every machine tool to a LAN network with plug-and-play technology [30]. This eliminates potential problems with adding and disconnecting new machines in information network. It is important to remember, however, that the straightforwardness of making changes in the machine park makes it difficult to plan the production ahead. This raises the need to use appropriate production planning software. A 14 day advance period appears to be a sensible planning horizon, but its applicability depends on the manufacturing specification of each company.

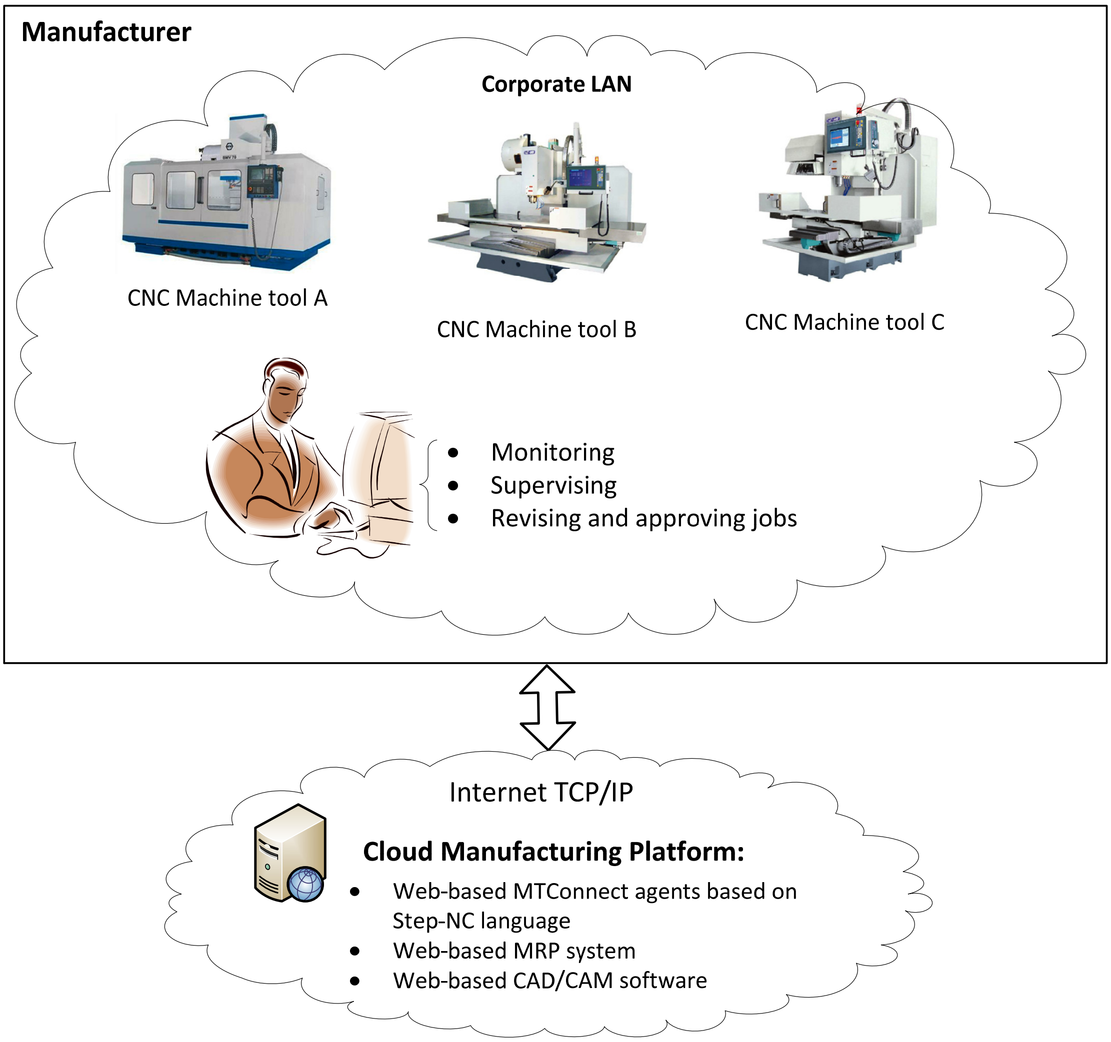

Figure 18. Cloud manufacturing resources and services
(*source: self study on the basis of [34]*)

Taking into consideration the capabilities of modern technologies and the complexity of this problem it is premature to assume that all tasks could be automatically (without operator's involvement) directed to individual machines. However, this issue should be properly analyzed and addressed by scientists and engineers in the future. Fig. 18 presents a surveillance diagram of companies associated in a manufacturing cloud with CNC machines and services implemented through a web portal.

In general, MTConnectstandard is limited to constant surveillance of the assets that belong to a business, but when interfaced with STEP-NC language this standard can also be used to launch discrete manufacturing tasks on individual machine tools ([5], [14], [35] and [36]).

6 Internet of things as a way of multimodal industries integration

As mentioned before Global Service Layer (see Fig. 4) which belongs to Enterprise domain includes a number of tools that can be used to adapt available software to a cloud. As a consequence all services can be adapted to PaaS delivery model. The success of cloud manufacturing concept depends on three basic factors: calability, flexibility and agility, all of which can be established by virtualization [13]. This raises the need for stable interconnections between physical devices and products. The key to efficient implementation of this task is the concept of Internet of Things which has been defined as “things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts” [24].

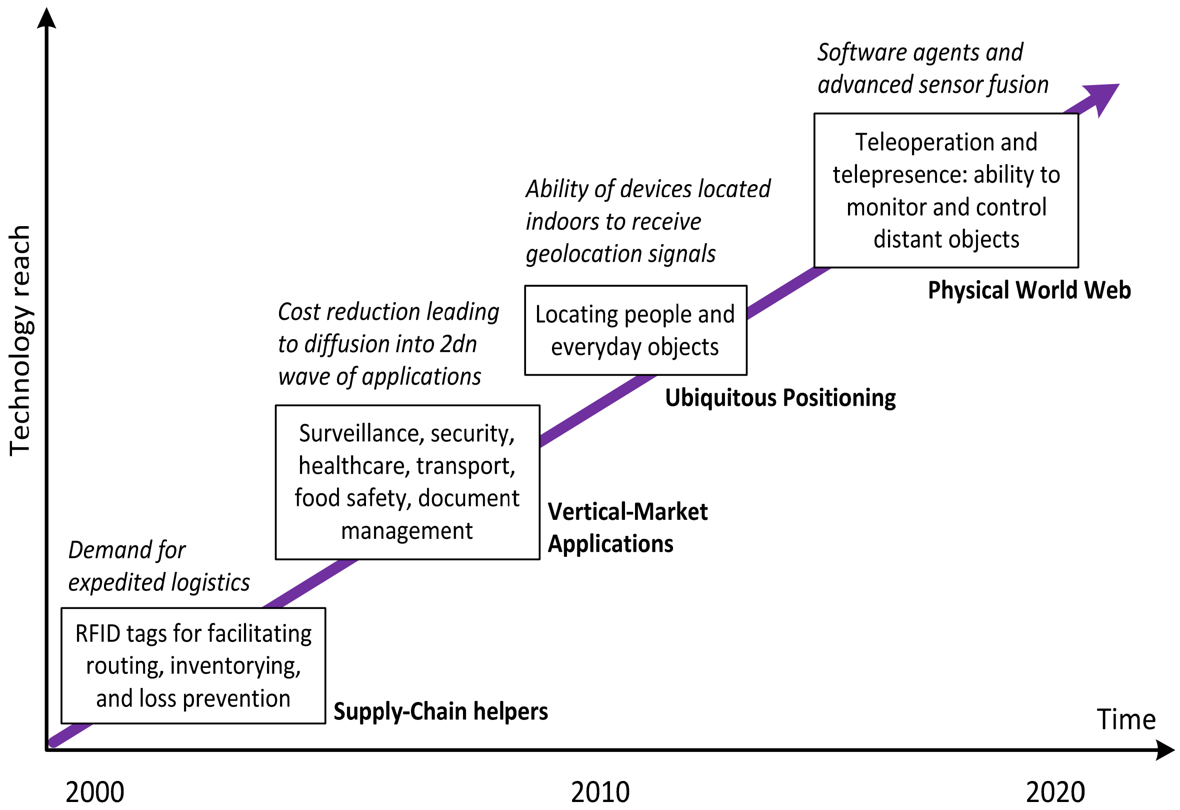

Figure 19. Internet of things – technology roadmap
(*source: [23]*)

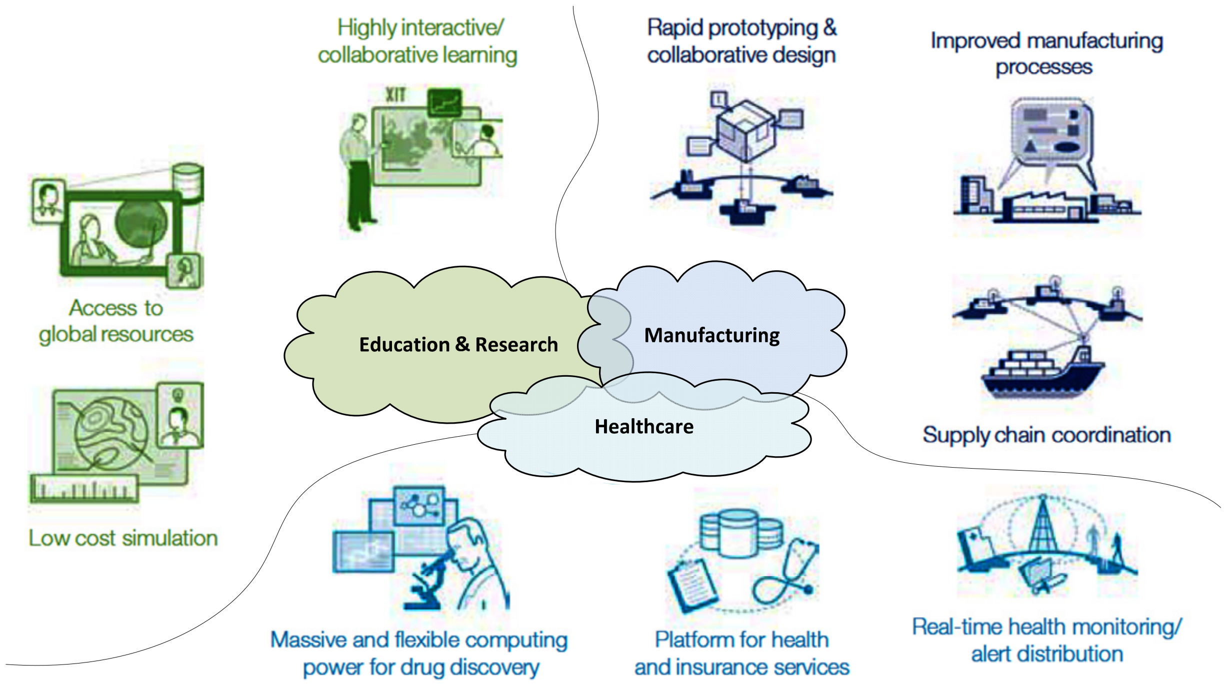

Figure 20. Potential use of cloud computing in multimodal industries
(*source: [33]*)

The direction of the evolution of Internet of things is presented in Fig. 19. As a result of a rapid technological development the drastic drops of market prices is a common phenomenon which improves the availability of the latest solutions.

The beginning of this century was marked with the invention of RFID (Radio-Frequency Identification) — a technology which, for example, allowed tracking goods in warehouses ([16], [17], [18]). This had a huge impact of logistical processes which fortified logistical branches of business. Further advancements were centered on decreasing the costs connected with making a purchase and implementing the technology that identifies physical resources. This reduction was made possible owing to numerous factors, such as creating application centered around industrial lines of business (e.g. security, healthcare, transport etc.), and the utilization of Electronic Product Code (EPC). The next stage in the evolution of Internet of Things, which we can witness now, is the widespread access to technologies which enable localizing goods and people inside a building. This phenomenon stems from the use of portable devices such as smartphones and Global Positioning Systems (GPS). The last prospective stage in the evolution of Internet of Things is Physical World Web. The attainment of such high technological level is conditioned by widespread (cheap or free) access to wireless Internet connections.

7 Opportunities for cloud-based integration of multimodal environment

The adaptation and implementation of cloud manufacturing to the manufacturing field is one of the possible ways to practically utilize the latest IT achievements. The overriding objective of all economic entities is the realization of the rudimentary manufacturing or service processes, and therefore in the enterprises not involved in IT operations directly, information technologies play auxiliary role. At the same time it is easy to observe that the highest dynamics of technological progress takes place in IT industries. In effect there is a significant disproportion between both categories of business. This phenomenon results in the reduction of technological progress on the macro scale. For example, the lack of adaptation in manufacturing sphere may prevent implementing the newest IT advancements. In this scenario, there is a huge potential for the development of the given industrial sphere, although there are still no simple and affordable solutions which would encourage the shift to the new method of providing goods and services. There's an important obstacle which slows down the progress in the automatization of manufacturing process - the multimodal diversity of manufacturing and service systems. The method of diversification is conditioned by assumed division criteria. The organization of manufacturing process defines two categories of production - discrete and process manufacturing. Taking into account business criterion we can distinguish the following manufacturing disciplines: automotive, consumer, electronics, industrial, chemical elements & allied products etc [27].

Multimodality is not limited to the manufacturing field. Looking at the higher levels of generalization other branches of economy can be observed — ones which just like manufacturing could take advantage of technological diffusion, particularly as far as cloud computing is concerned. Fig. 20 presents the areas that are expected to be affected by the diffusion of cloud computing concepts in the nearest future. Apart from manufacturing there are also three other spheres which are likely to implement cloud computing model – education and research, and healthcare. Within the realm of manufacturing the largest benefits are expected to be gained in rapid prototyping and collaborative design, manufacturing processes and supply chain coordination. Analogically, in the field of education and research the greatest promise of benefits is anticipated in: interactive & collaborative learning, global resources access, low cost simulation. On the other hand, healthcare has the best prospects in drug discovery, health and insurance services, real-time health monitoring and alert distribution.

8 Cloud operating models

The multimodality of those economic spheres is a serious barrier on the way to innovate business models with cloud computing solutions. Fig. 21 presents elements that should be integrated in a cloud model: clients, services, applications, infrastructure, platform and storage. The scheme above should be treated universally, which means it is adequate not only in building business models in the manufacturing realm, but also in other business spheres.

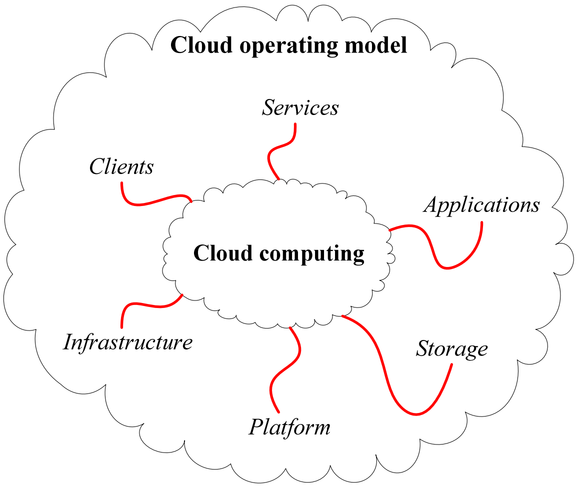

Figure 21. Cloud operating model
(*source: [32]*)

The use of cloud computing business model can secure certain tangible benefits (see Fig. 22). Some of the consequences of implementing cloud based solutions can be recognized almost immediately, while others become apparent after some time. The immediate effects include: increase in IT flexibility, improving IT and business process efficiency, reduction IT costs. he mid-term benefits are: a drop in the cost of failure, enhancement of collaboration, facilitation of business agility etc. The long-term macro-scale effects include: accelerated innovation, progress in R&D and science, creation of new jobs and businesses, empower individuals, promotion of sustainability, etc.

Adapting the concept of cloud computing in manufacturing environments grants many benefits which have been enumerated in this article. Those benefits stem from the utilization of the web portal as a platform whose function is to integrate varied cloud manufacturing ideas and elements. Due to the high levels of diversification of business models and operational strategies which are implemented by manufacturing enterprises, there may be the problem with preparing one unified business strategy which would be acceptable to all companies associated in the cloud. As early as during the process of designing MRP/ERP systems which will be offered in SaaS model, one of four possibilities should be taken into consideration [32]:

1) one sizefitsall,
2) a few standard operating models,
3) process-based "a la carte" flexibility,
4) unique operating model for each business model.

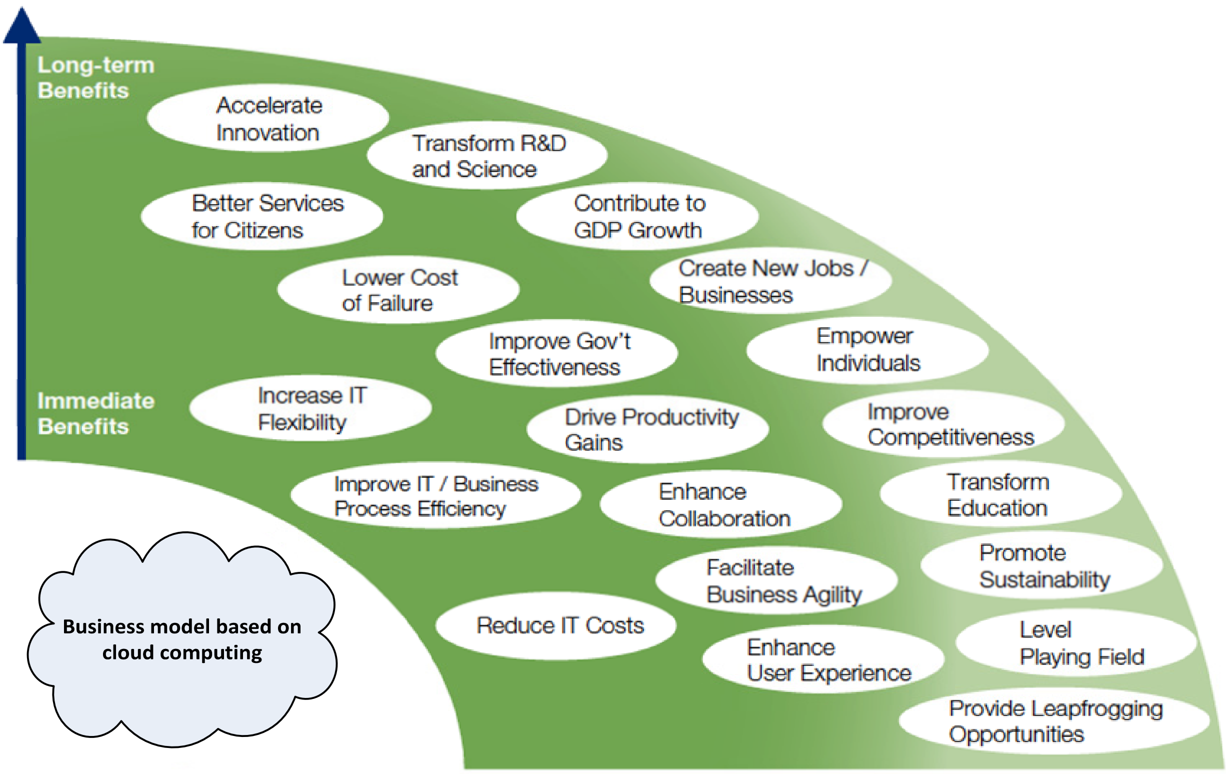

Figure 22. Potential use of cloud computing in multimodal industries
(*source: [33]*)

The chief advantage of One size fits all model is its simplicity, but many companies wouldn't be able to comply to its cornerstones on account of the specific nature of their ventures. The next operation model – a few standard operating model - involves creating two or three separate models, which are a little bit more detailed than their singular counterpart. Depending on enterprise the decision-making mechanism included in one of the services available in a manufacturing cloud would select the best operating model for a concrete manufacturing company.

As a consequence the proposed operating model would fit the enterprise specialty better, but the cost of this solution would higher as it would require preparing separate instances of MRP/ERP software. The third model called Process-based "a la carte" flexibility entails designing integrated business management system that could be characterized by variable processes. In effect, an automated decision making device or a human operator can select the methods of performing individual stages of the business processes form the available options. Assuming that these processes are subdivided into phases and each phase could be realized in two or three ways, this system would enjoy high customizability. The major disadvantage of such system would be the substantial cost of building the required software. The last operating model is unique operating model for each business model. According to its tenets each individual company ought to have its own separate system. From a company's perspective this is the best solution, but it is also the least practical because of the enormous costs of preparing independently working MRP/ERM class systems. Admittedly, those systems could be created in the course of collaboration between multiple designers and integrated into PaaS models which would consist of varied components available in a component cloud in the form of services. Nevertheless, the amount of resources consumed by the entire undertaking most likely would be too high to be acceptable.

9 Selecting a cloud business model provider

A practical realization of a web platform based on the concept of cloud manufacturing depends on the choice of appropriate SaaS, PaaS or IaaS solution. These services are usually provided through standardized interfaces such as Web Services, SOA [28] or Representational State Transfer (REST) [7].

Software-as-a-Service model is also sometimes known as AaaS (Application-as-a-Serivce). The term signifies that within the same public computing cloud many clients at once use common resources such as the service offered by an application and databases. For this reason this model is often referred to as Application Service Provider (ASP). There already are many service providers of this kind, the most important of whom are:

- NetSuite, that offers the system including powerful full-featured accounting, CRM, inventory, and ecommerce,
- Google Apps with Capable Online Productivity Suite that offers comprehensive suite of tools, good real-time sharing and collaboration features.

An important factor which reflects the effectiveness of SaaS model is its integration with other application. On this level the most important factors are: scalability, efficiency, accessibility, configurability and resistance to damage.

Platform-as-a-Service model supplies developers with a platform that can host a complete Integrated Development Environment, which can be used to fulfill the entire software release life-cycle. We discriminate the following stages of the life-cycle: development, testing, implementation and hosting of the advanced web application. All of the functionalities are services provided in a cloud. There are a number of integrated PaaS solutions available: Amazon EC2, Google App Engine, Netsuite, Daptiv, Bungee Labs, Coghead, Heroku, Rollbase, Microsoft Windows Azure and more. A PaaS platform offers a wide range of easily accessed services, which means that it can service multiple applications within the same platform.

Infrastructure-as-a-Service (IaaS) model is also sometimes referred to as Hardware as a Service (HaaS). IaaS constitutes a certain payment model for using this technology which relies on the frequency of the use of the equipment. This service is in particular convenient to corporate users, since it eliminates the need to invest in establishing and managing their own IT systems. The constant access to the latest software is a significant advantage of IaaS models. The company that employs this solution does not have to take care of technical details of IT structures they are using, which allows them to concentrate of their fundamental activities and making profit.

Table 4 presents a simple comparison of eleven selected IaaScloud computing technology providers [29].

The names of providers are placed in the table columns. The comparison of the providers was based on the following fifteen criteria:

1) Pricing Plan – this criterion is treated as better when more options is provided, but the pay-as-you-go model is the most wanted stand-alone option, because it allows the best usage control.
2) Average Monthly Price – this criterion reflects estimated cost (in USD) for a 1 CPU and 2GB RAM in cloud server. The value was averaged over datacenters for companies with location-based pricing, and averaged over Windows/Linux servers. When available, hourly pricing was used with assumption that one month includes 730 hours. Otherwise, monthly pricing was used. Data transfer costs are omitted.
3) Service Level Agreement (SLA) – this criterion reflects the proportionate uptime SLA.
4) Number of Datacenters – this criterion describes the number of available datacenters when cloud servers are deployed.
5) Certifications – this Boolean type criterion reflects compliance and security-related certifications (e.g. PCI or SAS 70).
6) Scale Up – this Boolean type criterion reflects possibility of scaling up individual cloud server instances by adding e.g. more memory, extra CPUs, more storage space etc.
7) Scale Out – this Boolean type criterion describes possibility of quick deploying new server instances.
8) Support – this is the three-level criterion:
   a) poor – encompasses providers that the free offer includes on-line forums only but any other support must be paid,
   b) average – encompasses providers that offer an extra free support (via phone or on-line chat), apart from forums,
   c) extensive – encompasses providers in which the base price covers multiple support offerings.
9) Monitoring – this criterion is 3-level scaled:
   a) poor – including providers with no monitoring and alert solutions, requiring the third-party tools deployment or there is the need to use of extra services,
   b) average – including providers with very simple integrated monitoring tools (not much indicators, no alerting),
   c) extensive – encompasses providers with fully integrated monitoring tools that are included in price.
10) APIs – this 3-stage criterion (None, Average, Extensive) describes the level of offering of Application Programming Interfaces to interact with the servers.
11) Free Tier – this Boolean type criterion is set "Yes" when the provider allows "free trial" tier that customers can use to test the service.
12) Supported operating systems (SOS) – this criterion reflects the number of supported operating systems.
13) Number of Instance Types – this criterion reflects the available number of different server configurations. "Configurable", means that provider offers fully customizable server.
14) Transfer Cost-out – cost of outbound data transfer calculated in USD for each GB of outbound data sent from the server. Zero means that given provider offers a "per second" (Mbps) connection for free.
15) Transfer Cost-in – cost of inbound data transfer calculated the same way as above.

Table 4 was divided into two parts. The information in the upper part concerns individual service providers and criteria. The data from the upper segment of the table are qualitative and quantitative in character. The lower part of the table contains the ranking of service providers that came about as a result of transforming descriptive information into actual figures.

The higher the numbers for the higher position in the ranking. The maximal value of each criterion is 1; the minimal equals 0. Formula 4 was used to calculate the final score for each provider.

$$S_j = N^{-1} \sum_{i=1}^{N} c_{ij} w_i \tag{3}$$

where: S_j – final score of provider j, N – number of criteria (in this case N=15), c_{ij} – value of criterion i for provider j, w_i – weight of criterion i (in this case $w_{1..N} = 1$).

Table 4 . Comparison of different IaaS providers
(source: self-study on the basis of [29])

Provider / Criterion		Amazon EC2	Bit Refinery	Go-Daddy	GoGrid	Host-ing.com	Nepho-Scale	Op-Source	Rack-space	Relia-Cloud	Soft-layer	Terre-mark
Pricing	1	Pay-as-you-go or Year + Discount	Monthly	Monthly	Pay-as-you-go or Monthly	Monthly	Pay-as-you-go or Year + Discount	Pay-as-you-go or Monthly	Pay-as-you-go	Monthly	Pay-as-you-go or Monthly	Pay-as-you-go
Average Price / Month (US$)	2	80,81	137	39,99	273,6	270	146	87,6	51,1	135,05	135,05	133,39
SLA	3	99,95%	100%	99,90%	100%	100%	99,95%	100%	100%	100%	?	100%
Datacen-ters	4	7	1	8	2	4	1	4	9	2	7	9
Certifica-tions	5	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Scale Up	6	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Scale Out	7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Support	8	Poor	Extensive	Exten-sive	Exten-sive	Extensive	Average	Extensive	Exten-sive	Average	Poor	Poor
Monitor-ing	9	Extensive	Poor	Poor	Poor	Average	Poor	Average	Exten-sive	Poor	Exten-sive	Poor
APIs	10	Extensive	None	None	Average	None	Extensive	Extensive	Exten-sive	Average	Exten-sive	Average
Free Tier	11	Yes	No	No	No	No	Yes	No	No	No	No	No
SOS	12	9	3	4	4	3	4	4	8	5	6	5
Instance Types	13	12	Configu-rable	5	1	Configu-rable	6	Configu-rable	8	5	13	Configu-rable
Transfer Cost - out (/GB)	14	0,12	0	0	0,29	0	0,13	0,15	0,18	0,12	0,1	0,17
Transfer Cost - in (/GB)	15	0	0	0	0	0	0	0	0	0	0	0,17
		Scoring										
Pricing	1	0,60	-	-	1,00	-	0,60	1,00	0,30	-	1,00	0,30
Average Price / Month (US$)	2	0,70	0,50	0,85	-	0,01	0,47	0,68	0,81	0,51	0,51	0,51
SLA	3	0,75	1,00	0,50	1,00	1,00	0,75	1,00	1,00	1,00	-	1,00
Datacen-ters	4	0,78	0,11	0,89	0,22	0,44	0,11	0,44	1,00	0,22	0,78	1,00
Certifica-tions	5	1,00	1,00	-	-	1,00	-	1,00	1,00	1,00	1,00	1,00
Scale Up	6	-	1,00	-	1,00	1,00	1,00	1,00	1,00	-	-	1,00
Scale Out	7	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Support	8	-	1,00	1,00	1,00	1,00	0,50	1,00	1,00	0,50	-	-
Monitor-ing	9	1,00	-	-	-	0,50	-	0,50	1,00	-	1,00	-
APIs	10	1,00	-	-	1,00	-	1,00	1,00	1,00	1,00	1,00	1,00
Free Tier	11	1,00	-	-	-	-	1,00	-	-	-	-	-
SOS	12	1,00	0,33	0,44	0,44	0,33	0,44	0,44	0,89	0,56	0,67	0,56
Instance Types	13	0,46	1,00	0,19	0,04	1,00	0,23	1,00	0,31	0,19	0,50	1,00
Transfer Cost - out (/GB)	14	0,59	1,00	1,00	-	1,00	0,55	0,48	0,38	0,59	0,66	0,41
Transfer Cost - in (/GB)	15	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	-
Final Score		**0,73**	**0,60**	**0,46**	**0,51**	**0,62**	**0,58**	**0,77**	**0,78**	**0,50**	**0,61**	**0,59**

In the analyzed scenario it was assumed that the weights of all criteria are equal. The winner of the ranking was Rackspace with the final score of 0,78.

10 Conclusions

The article touched upon the novel concept of cloud manufacturing – an idea heavily grounded in cloud computing model. At the beginning the paper explained three different business models – SaaS, PaaS and IaaS, which operate within cloud manufacturing frameworks. Next it highlighted rudimentary requirements that need to be fulfilled in order to open a web portal, which could aid manufacturing processes. Cloud manufacturing relies on high level of process automatization concerning manufacturing orders, developing technology, machine and contractor selection as well as appraisal and offering. The article discussed many aspects of cloud manufacturing system architecture and identified key obstacles that may make the process of commercialization of this innovative solution more difficult. It also concentrated on the question of matching different machines to different manufacturing orders. The paper analyzed possible solutions to this challenge: using a tested algorithm or taking advantage of classic fuzzy interface system (FIS) which would perform multicriterional selection tasks. It showed how simultaneous progress in related information technologies (e.g. Internet of Things) can improve the performance of cloud computing. The next part of the article dealt with promising segments of economy that potentially can bring profits, and that can be developed only with cloud technologies in use. The paper presented multiple operating models, according to which the manufacturing processes can be organized.

This ranking can be referenced when deciding between SaaS, PaaS or IaaS service providers. Cloud manufacturing is currently in the infant stages of development. At present there are no commercial solutions of this type, although pilot system are being created – ones which realize the chosen tasks characteristic to cloud manufacturing. In multimodal economic, administrative and social environments this translates into full automatization of manufacturing processes. It appears that however distant this strategic objective is, it will constitute a goalpost for many researches in the next few years to come.

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THE RISK ASSESSMENT IN THE LOGISTIC PROCESSES STRUCTURES

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Abstract: This paper presents the nature of logistic processes functioning in manufacturing companies with special risk factors situations. The author's parameterization model of the value added was generated as a result of the logistic processes. Author refers to differences between all-in and real costs caused by appearance of risk factors in logistic processes. Author also identifies the change of the value added measured with the net profit and its results.

Key words: logistic process, risk, value added, characterization principle, all-in/total cost, real/actual cost.

1 Introduction

It is in the opinion of the author that the risk management in logistic processes has a significant impact on the value added created by a manufacturing company both for customers as well as for the company itself. The comprehensive identification and the quantification of the processes in terms of the value added creation constitute the base of the identification of risk factors and, what is associated with it, also a base for implementing the risk management system in logistic processes. It should be therefore possible to build a parameterization model by means of the tools of the mathematical logic, in particular with the application of the propositional functions in the description of cause-and-effect and structural relationships, which are so characteristic for operations of manufacturing companies.

2 The adopted meaning of the crucial categories of the subject

These are supply, production and distribution that are the fundamental operation areas of any manufacturing company. The logistic processes combine the business process of supplying with the technical production processes and the production with the business process of distribution. These are the activities accomplished by them that are their attributes as: storing, transport, trans-shipment, packing, labelling, handing over and preparing orders [20].

These activities transform initial resources into final resources with the changed value added. Thus the level of the value added acquired at the end of the process, depends on the sum of transformations carried out during individual activities being included in the specific process. Hence, it is the transformation that determines whether we obtain the expected level of the value added. Each step of the process should raise the value of the product, that is create its value added for a customer and/or for the company. Therefore the adequate protection of the transformation, for example by a risk management system, determines the definitive level of the value added obtained as a result of the process.

It is for the purposes of the paper that the processes, which support the main activities of the company during the transformation through coordinated storing, transporting, trans-shipment, sorting, packing and labelling will be ranked among logistic processes enabling maximizing the created value added for outside and internal customers [18].

One should pay attention to the fact, that every organization performing everyday tasks is exposed to many kinds of different risk factors. Many of them are connected one with another, which means that one type of the risk may cause arising another risk factor. Hence, the identification of the reasons and sources of risks determines the reduction or the minimization of the risk to the accepted level [24], which is directly translated into implementation of the objectives of the processes.

The essence of the transformation protection in the logistic processes means the presence of specific (typical) risk factors for the logistic processes, which have certain probability (frequency of appearing) and cause defined effects (expressed as costs). The risk factors appearing in logistic processes affect the change in value added accomplished by main processes of the organisation. This change has most often a negative result [18].

There are not many methods described in the literature on the subject, which are helpful while analysing and controlling risk factors appearing in the logistic processes.[1] Therefore, there is a need of developing a new method in order that one could take optimal decisions and thus reduce the influence of risk factors associated with logistic processes on creating the value added. The effect of the research conducted in this respect was described in the next subsections of the paper.

3 The logistic processes from the functional and structural perspective of the characterization principle

It is according to the adopted definition of the process that it is a juxtaposition of consecutive activities, which are repeated in the determined cycle and which transform resources into the outcome of the process. The transformation consists in conferring a new value (value added). The measurable objective of the process is the achievement of the result of the highest value added verified and recognised by a customer.

Such an approach facilitates the optimization of the company as a whole, since the boundaries amongst departments obstructing the communication, are replaced by the boundaries amongst processes. As a result, it is the outcome of the process that becomes the general objective and these are processes and their results that are the sources of delivering products to customers. The logistic processes support functioning of the management system and ensure its effectiveness and efficiency. They include activities and actions associated with the preparation of the structure of the main processes, the management of the information system creation, transport, storing, accounting, finances, reporting and controlling [22].

It is the coordination of all activities in the company that appears as a part of logistic processes. The aim of the coordination is to obtain the unanimity in the accomplishment of the task, of which components the activities are. The key to the coordination is the insight into the internal structure of contractors and the determination of their objectives. The logistic processes appear, when there is the need to coordinate the main processes one with another in the manufacturing company.

The structural and functional character of the relations appearing in the logistic processes points to the possibility of the use of the characterization principle for the parameterization of the value added of the results of the logistic processes. Moreover, it is taking into account the logistic processes, the risk management as well as problems of the value creation that provides simultaneously the bases of appointing a new area of research in the form of the Axiological Dimension of the Risk Management (ADRM) in the logistic processes. ADRM in the logistic processes should be defined as the integrated, structured instrumentation, being aimed at the identification and the accomplishment of the logistic processes supporting creation of the value added and eliminating risk factors disturbing the process of creating the value for internal and external customers. The base is the use of the potentials inherent in the synergetic effects obtained through the use of the premises integrating the management of logistic processes, of the creation and the accomplishment of the value added and of the risk as a crucial determinant of processes of the value creation [18].

In case of the ADRM modelling of logistic processes, one should simultaneously take into account such parameters as [18]:

- the process of the value creation,
- the identification of the risk factors,
- the probability (frequency) of appearing of risk factors,
- the effects triggered by risk factors,
- the logical, temporary, priority, hierarchical and functional relations,
- the conditions for the transformation,
- the inputs (supply) for processes,
- the outputs (the effects of the accomplishment) of processes,
- the result of the accomplishment of processes.

Given the multiplicity of possible states that can be taken by these parameters, we deal with the situation, which implies the need to generate and to evaluate a set of many possible solutions, which can appear in the given problem situation.

[1] The conclusion was based on the research conducted on the group of manufacturing companies quoted on the Warsaw Stock Exchange in Warsaw in 2004-2008. It is amongst many presented proposals of analysing, controlling or even managing risks that no optimum one was found for the evaluation of the result (value added), which arose as a result of the accomplishment of logistic processes.

As the number of elements of the set of the solutions for most practical problems grows in the NP-complete way, there is no practical possibility of seeking and considering each of them in the real time. Hence, the need of seeking solutions appears, which could enable the selection of the variants to be evaluated and allow for narrowing the space and reducing the time of finding interesting solutions. Such possibilities are provided by the characterization principle developed by V.A. Gorbatov.

The characterization principle is one of the modern methodological apparatus of the systems theory. The system interpretation of tasks in accordance with this principle is based above all on:

- the determination (search for) of not very solutions but their distinctive features,
- the features should be related to representatives (to invariants) of classes of equivalent solutions,
- a class of equivalent solutions is formed as a result of interpretation of input data of the considered group of tasks in categories of features of solutions ([6], [7], [8], [11], [12], [13] and [14]).

There are usually fewer equivalent solutions than all possible solutions, and the analysis of features of solutions can be conducted without their direct generation (objective). The formally developed and verified characterization principles within the given objective area create the characterization theory. Its essence is contained in the mutual interpretability of the operating model of the examined object with the model of its structure. The mutual interpretability of the models is achieved by the selection of universal laws of correct functioning (expressed in the operational model) and structural interpretation of the operating model [6].

According to the characterization principle, an object will function correctly, if it will be possible to identify and to prove a mutually consistent interpretation between its operating rules (described by the operational model, which is denoted by ψ_a) and the implementing structure (described by the model of the structure, which is denoted by ψ_b). It is in order to determine and to prove the explicit interpretation of these two models that the following assumptions are adopted:

- a resource functions adequately to its structure,
- a structure of the resource is appropriate to its desirable way of functioning.

The essence of the characterization principle can be written as [6]:

$$< \psi_a, \psi_b, P_0(\psi_a, \psi_b) > \quad (1)$$

where:
ψ_a – operating model,
ψ_b – structural model,
$P_0(\psi_a, \psi_b)$ – atomic predicate.

The atomic predicate P_0 (ψ_a, ψ_b) characterizes the possibility of interpretation of the ψ_a operating model in terms of the ψ_b structural model. The P_0 predicate is a particular case of the logic variable and takes the value "1" or value "0". "1" means the possibility of mapping, whereas "0" lack of such possibility.

It is applying the characterization principle in the ADRM of logistic processes that requires precise determination:

- what is the operating model in ADRM of logistic processes?
- what is the structural model in ADRM of logistic processes?
- how should the predicate $P_0(\psi_a, \psi_b)$ be interpreted?

Developing the theory of the conditions for converting the ψ_a model into the ψ_b model for construction of the ADRM parameterization model of logistic processes requires:

- the set of ψ_a operating models in terms of the ADRM of logistic processes including the information on:
  - probability (frequencies) of appearing of risk factors in logistic processes,
  - effects of appearing of risk factors (defined as the maximum cost caused by them, when they appear in logistic processes) as well as,
  - the achieved (planned) value added, adequate for all examined manufacturing companies with regard to the period of the research (2004-2008).
- the set of the ψ_b structural models in terms of the ADRM of logistic processes including the information on:
  - continuity of the course of logistic processes supporting main processes in the manufacturing company,
  - real costs (the effects and the probability) of appearing of the defined risk factors in logistic processes,

- the achieved (real) level of the value added in the obtained outcome of the process adequate for all examined manufacturing companies with regard to the period of the research (2004-2008).

- the atomic predicate P_0 (ψ_a, ψ_b) determining the mutual interpretability of the operating model in terms of the structural model [18].

The set of ψ_a operating models in terms of the ADRM of logistic processes reflects risk factors identified in all processes supporting the main activity of examined manufacturing companies. After having analysed the literature and the empirical research, it was established that they should be grouped into the risk factors concerning the most essential areas and functions from the point of view of the appearing logistic processes, i.e.: of supply, production, distribution, transport, storing and managing logistic processes.

It is among the risk factors identified that there were such ones, which can be found at any stage of the accomplishment of the supporting processes and such ones, which concern only the chosen logistic areas ([9], [18]). Therefore, the next step was to assign the risk factors to the appropriate logistic areas.

Based on findings, the following assignment of risk areas and risk factors was made:

- supply - the risk factors concerning supply, transport, storing and managing logistic processes,
- production - risk factors concerning production, transport, storing and managing logistic processes,
- distribution - risk factors concerning distribution, transport, storing and managing logistic processes,
- transport - risk factors concerning transport and managing logistic processes,
- storing - risk factors concerning storing and managing logistic processes,
- managing logistic processes - risk factors concerning managing logistic processes [18].

It is for formulating the operating model that the information on the frequency of risk factors appearing in the selected areas of logistics was required. The presence of risk factors in the given area of logistics in the given year was denoted as "1" in the operating model. If the risk factor did not appear in all areas or in all functions in the given year, it was not included in the propositional function.

It is on the basis of the data describing the probability and the effect of appearing of the risk factors in logistic processes for any manufacturing company that it is possible to develop an operating model in the form of the system of propositional functions, which describe relations and the ADRM structure of logistic processes, i.e. such propositional functions, which will include the information on the presence of risk factors with the defined effect and probability in logistic processes and which affect the created value added in the given period of time - here: 1 year.

On this base, it can be concluded that the operating model includes information on all-in costs of the presence of risk factors in logistic processes, since these are the data mapping the current state of the research problem established on the basis of studies in the given company and in the given time period.

In fact, the costs of the presence of the risk factors are most often higher than the ones, which are shown in income statements. It is to obtain the information on the real costs caused by risk factors that an interpretation of the structural model is essential. Obtaining the structural model requires the accomplishment of the consecutive stages of the characterization principle.

The set of Ψ_b structural models in terms of the ADRM of logistic processes must include information on the real costs of the presence of risk factors in logistic processes translating into the size of the value added achieved by the given company. It is achieving this result that requires, according to the characterization principle, determining conditions of redesigning the operating model into the structural model so as that its components would create a partially ordered set, i.e. the set whose elements $P_i^{\sigma_i}$ meet the requirements of the partial ordering:

$$R \subset P \times P \; (P_i^{\sigma_i} \in P)$$

described with properties:

- reflexivity:

$$\forall (P_i^{\sigma_i} \in M)[(P_i^{\sigma_i}, P_i^{\sigma_i}) \in R]$$

- antisymmetry:

$$\forall (P_i^{\sigma_i}, P_j^{\sigma_j} \in M) \{[(P_i^{\sigma_i}, P_j^{\sigma_j}) \in R] \wedge [(P_j^{\sigma_j}, P_i^{\sigma_i}) \in R] \rightarrow P_i^{\sigma_i} = P_j^{\sigma_j}\}$$

- transitivity:

$$\forall(P_i^{\sigma_i}, P_j^{\sigma_j}, P_k^{\sigma_k} \in M)\ \{[(P_i^{\sigma_i}, P_j^{\sigma_j}) \in R] \wedge \left[\left(P_j^{\sigma_j}, P_k^{\sigma_k}\right) \in R\right] \rightarrow (P_i^{\sigma_i}, P_k^{\sigma_k}\} \in R\}$$

where:

R – the relation symbol,

P – the set of risk factors,

$P_i^{\sigma_i}, P_j^{\sigma_j}, P_k^{\sigma_k}$ – the elements of the set of risk factors,

M – the set of propositional variables.

The partial ordering relation fully corresponds to the assumptions of the ADRM of logistic processes while we consider the need for mapping the processes in the defined areas as well as the specific risk factors resulting from such assignment.

An appropriate way of presentation of the structural model is the Hasse diagram, since it is a directed graph, which reflects the ideas of the process implementation as a sequence of consecutive steps with the appearing risk factors. It is formulating the Hasse diagram that requires removing all loops from the graphical presentation of the process, i.e.: repeated or duplicated activities (that corresponds with the reflexivity in the partially ordered set) as well as closing arcs, which reflect for example improperly marked internal transport routes, improper or lack of marking fields of storing in magazines, etc. (which corresponds with transitivity in the partially ordered set).

It is finding the optimum Hasse diagram that requires converting the ψ_a operating model into the ψ_b structural model in such a way that the propositional function being in the ψ_a model would be unambiguously interpreted in the ψ_b model.

In the assumptions of the characterization theory, the universal laws of correct functioning are expressed by means of the so-called prohibited graph figures, defined as abstract structures, which should not appear in form of homeomorphisms in the operating model "under threat" of its incorrectnesses ([6], [19]) what originally was applied in the automata theory [6].

In particular, the methodology of the complementary support by designing logical structures for automata according to Gorbatov is based on a sequence of model exchanges with regard to the principle of the prohibited graph figures ([5], [4]). Therefore, among other things, the minimization of Boolean functions based on algebraic and logic records with the use of prime implicants can be carried out according to structural properties ([1], [2] and [3]), but such issues of the minimization from the automata theory, have not to be directly applied from the standpoint of logistics processes.

It is for the ADRM parameterization model of logistic processes that the identification of the prohibited figures in the form of graph Q^A or Q^B submodels is most significant. The prohibited Q^A figure is a graph submodel recorded in the form of cycle with odd length, whose apexes are weighed with pairs of cyclically changing weights, which are indexes of appropriate alternative elements [19] (see Fig. 1).

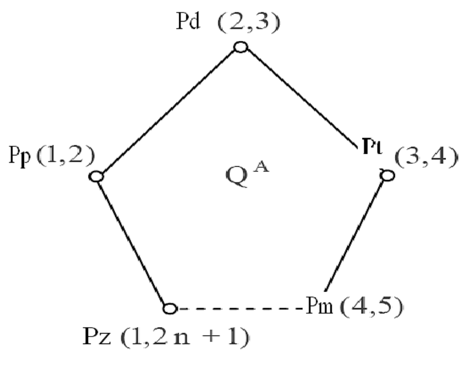

Figure 1. The Q^A prohibited graph figure
(*source: drawn up on the base of: [19, p. 144]*)

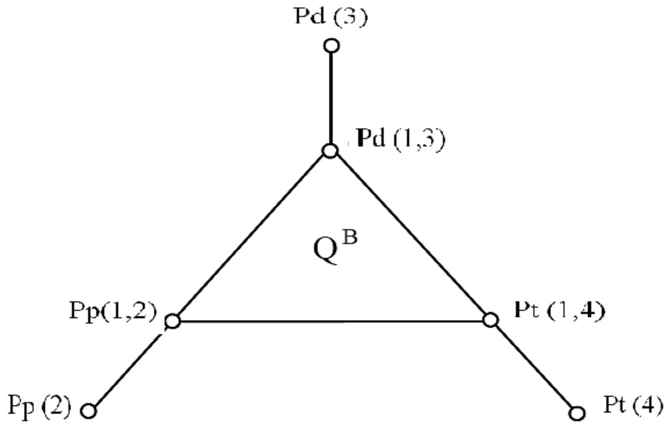

Figure 2. The forbidden graph figure Q^B
(*source: drawn up on the base of: [19], p. 144]*)

It is for the ADRM parameterization model of logistic processes that such a graphical form informs us about the presence of risk factors in more than one area of significance of processes. It is very important from a point of view of the cost analysis concerning removing effects of the presence of risk factors, since the effects will be noticed in many areas (the number depends on a specific case) of functioning of any company and this will multiply costs and translate into a reduction in the value added in this way. The second kind of the prohibited figure is the Q^B figure, which is a graph submodel recorded in the form of the triangle with hanging vertexes (see Fig. 2). Vertexes of the triangle have an identical weight and additionally each of them has the additional weight equal of the weight of the hanging vertex [19].

This kind of a prohibited figure corresponds to the situation, when the risk factors present in one area affect the adjacent ones, e.g. a risk factor associated with transport (let's denote it as a) triggers a risk factor in supply (let's denote it as b) and simultaneously triggers a risk factor in production (let's denote as c) as well as in the area of distribution (let's denote it as d). It is removing the initiator, that is splitting the prohibited graph figure according to the characterization principle through splitting the factor "a", that will eliminate effects in four areas.

While splitting prohibited graph figures, one should take the following issues into account:

- the splitting should be carried out in such a way that all prohibited graph figures will be eliminated,
- it is out of possible variants of splits (replicas of variables) that we always choose the minimal subset of propositional variables, which will cause the elimination of all prohibited graph figures,
- it is to choose from possible variants of splitting propositional variables that we use a semantic decision table,
- the choice of a variable/variables for splitting conditions the form of the new ψ'_a operating model, and hence the form of the resultative Hasse diagram.

It is obtaining the new operating model and the determined form of the Hasse diagram that has its consequences for ADRM of logistic processes. The conducted operations are followed by splitting the propositional variables. In terms of ADRM of logistic processes, these variables reflect risk factors present in the studied areas of logistic processes, being characterized by a determined probability and an effect of presence of risk factors, i.e. doubling activities will be reflected by the final cost level. Through applying the characterization principle, it can be noticed in a simple way that the presence of risk factors has its consequences not only at the place of the occurrence but also the effects often affect other areas of functioning of an enterprise and even of the entire organization. Once the characterization is completed, we can calculate real costs of the appearance of risk factors.

It is through comparing total and real costs of the appearance of risk factors that it is easy to notice how important their proper calculation is. The consequences of underestimating the costs associated with removing the effects of undesired events are visible in the profit and loss account of each enterprise.

The application of the characterization principle to the ADRM parameterization of logistic processes is associated above all with showing actual costs actually incurred in connection with the occurrence of certain risk factors in logistic processes. After having conducted the analysis with the use of the ADRM parameterization model of logistic processes, it is possible to demonstrate that actual costs of the risk are higher, than the ones included in calculations (if they are reported at all). The disregard of the real costs of the presence of risk factors, can significantly affect creation of the value added, translating into conditions for functioning of an enterprise on the market.

The presence of risk factors in manufacturing companies while caring out logistic processes has mainly negative economic influence, which manifests itself in increasing costs of logistic processes, causing loss of the determined level of the value added. It is in order to be able to operate on the market that any company has to be competitive and has to make profit, despite the existence of a constant opposite trend in the form of the presence of many risk factors.

4 The application of the characterization principle in the risk assessment in logistic processes

Following the requirements of the characterization principle, one should for the ADRM of logistic processes:

- make a formal record of the studied fragment of reality in the form of the system of propositional functions,
- develop an operating model of the studied fragment of reality, through the analysis of the function, the elimination of the forbidden graph figures from the model of the propositional function with the use of the semantic decision table as well as splitting the ψ_a graph operating model,
- find its structural (technical) interpretation in the form of the graph structural model in the form of Hasse diagrams for the developed operating model.

It is obtaining information on actual costs, which are incurred by the company in relation to the presence of risk factors showing structural-functional relations of the model that was described on two examples. For carrying out the analysis, the ADRM[2] simulator will be used. It is basing on the data obtained in the E Company during conducted examinations in the years 2004 - 2008 that we determine propositional function describing the presence of risk factors in logistic processes, which translate into creation of the value added of the company. The propositional function is obtained by selecting the first module of the model of the propositional function. We enter the list of risk factors present in the company and information on the probability and the effects of their presence. It is in order to obtain the propositional function that we choose the company, the determined year and we mark these risk factors in the "choice" column, which are supposed to be analysed by us (see Fig. 3).

It is on the basis of the data of the E Company that there were indicated 9 of 81 important risk factors from the point of view of logistic processes of this company (the full list of risk factors of the E Company: [9]). On this base, the propositional function adopted the following form:

$$ZP_x(P_1, P_2,\ldots, P_{81}) = P_7\, P_{49}\, P_{81} \vee P_7\, P_{52} \vee P_{30}\, P_{46} \vee P_8\, P_{46}\, P_{81} \vee P_{46}\, P_{60}\, P_{67} \vee P_{30}\, P_{52}\, P_{67}$$

The semantic interpretation of the propositional function shows that it was amongst crucial ones that there were the following factors in the area of supply: promptness of deliveries (P_7), decrease in the number of orders (P_{49}), shortage of capital (P_{81}); in the area of production: promptness of deliveries (P_7), lack of a system of the in-house transport (P_{52}); in the area of distribution: mistake in estimating profitability of a customer (P_{30}), not keeping order fulfilment times (P_{46}); in the area of transport: changes in supply conditions (P_8), not keeping order fulfilment times (P_{46}), shortage of capital (P_{81}); in the area of storing: not keeping order fulfilment times (P_{46}), lack of the detailed data regarding individual stocks (P_{60}), problems in the flow of information (P_{67}); whereas in the area of managing logistic processes: mistakes in estimating the profitability of a customer (P_{30}), lack of organization of in-house transport (P_{52}), problems in the flow of information (P_{67}).

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[2] The ADRM simulator is an author's software, which among others enables conducting economical experiments according to the characterization principle of V.A. Gorbatov. The application is available on: www.e.kulinska.po.opole.pl. It is for conducting experiments according to the characterization principles that there are four modules placed on the right side of the screen: the propositional function model, operating model, semantic decision table, structural model - Hasse diagrams.

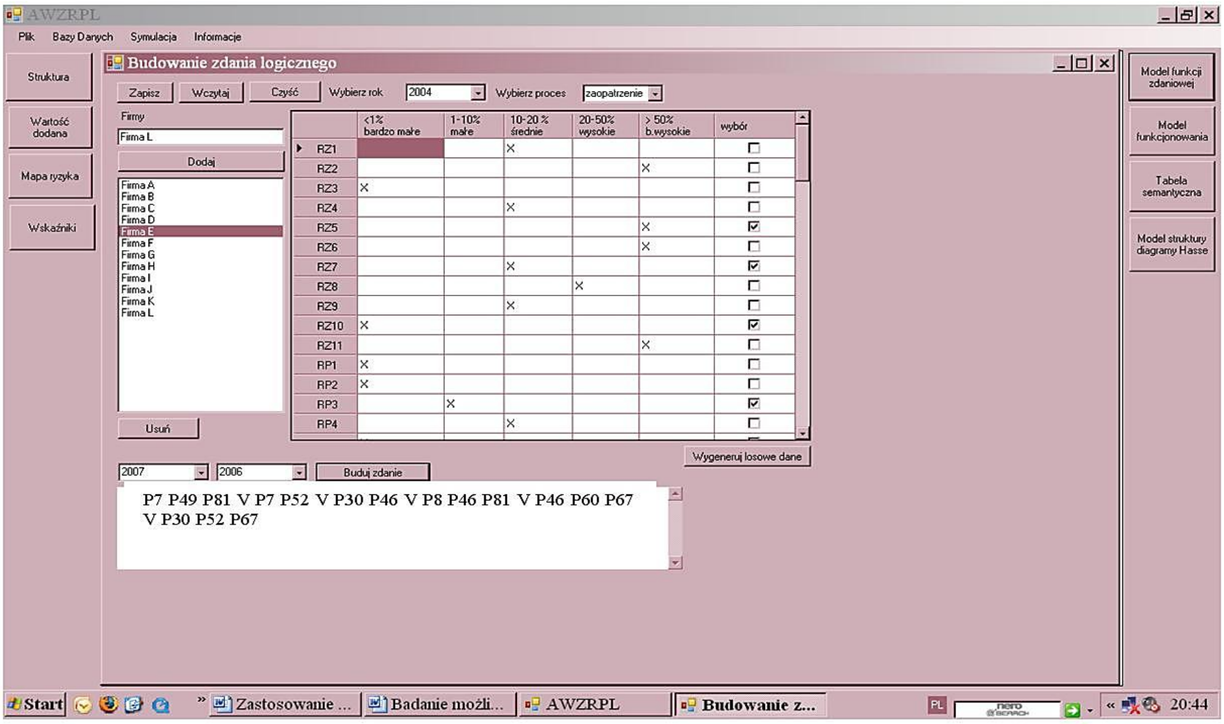

Figure 3. An active window of the module - a model of a propositional function
(*source: own study*)

The ψ_a operating model of the ZP_x propositional function is set as the juxtaposition:

$\psi_a = < M, R_2, R_3>$

where

M - the set of propositional variables;.

R_2 - the set of relations defined by dual element alternative modules describing the areas of production and distribution.

R_3 - a set of relations defined by three elements alternative modules describing the areas of supply, transport, storing and managing logistic processes).

$M = < P_7, P_8, P_{30}, P_{46}, P_{49}, P_{52}, P_{60}, P_{67}, P_{81}>$

$R_2 = \{\{P_7, P_{52},\}_2, \{P_{30}, P_{46}\}_3$

$R_3 = \{\{P_7, P_{49}, P_{81}\}_1, \{P_8, P_{46}, P_{81}\}_4, \{P_{46}, P_{60}, P_{67}\}_5, \{P_{30}, P_{52}, P_{67}\}_6\}$

The module "operating model of the ADRM simulator" enables to obtain a graphic form of the operating model Fig. 6.

The graphic form is created in the following way. It is for each propositional variable present in the operating model that the number of the conjunction is determined, in which there are: $P_7(1,2)$, $P_8(4)$, $P_{30}(3,6)$, $P_{46}(3,4,5)$, $P_{49}(1)$, $P_{52}(2,6)$, $P_{60}(5)$, $P_{67}(5,6)$, $P_{81}(1,4)$.

The propositional variables are vertexes of the graph. The propositional variables present in the same conjunctions are connected with lines. Thus, it is in the Fig. 4 that the propositional variables present in the first conjunction are connected with the red line, in the second one with the green line, in the third one with the blue line, in the fourth one with the black line, in the fifth one with yellow line, in the sixth one with purple line.

It is a structural model that is an aim of modelling and solves a defined research problem, that is searching for actual costs of presence of risk factors in logistic processes, which are translated into reduction in the value added realized by a company. It is obtaining the result that requires limiting the structural model in such a way that its P_i elements would create a partially ordered set, i.e. the set, whose elements keep partial ordering relation.

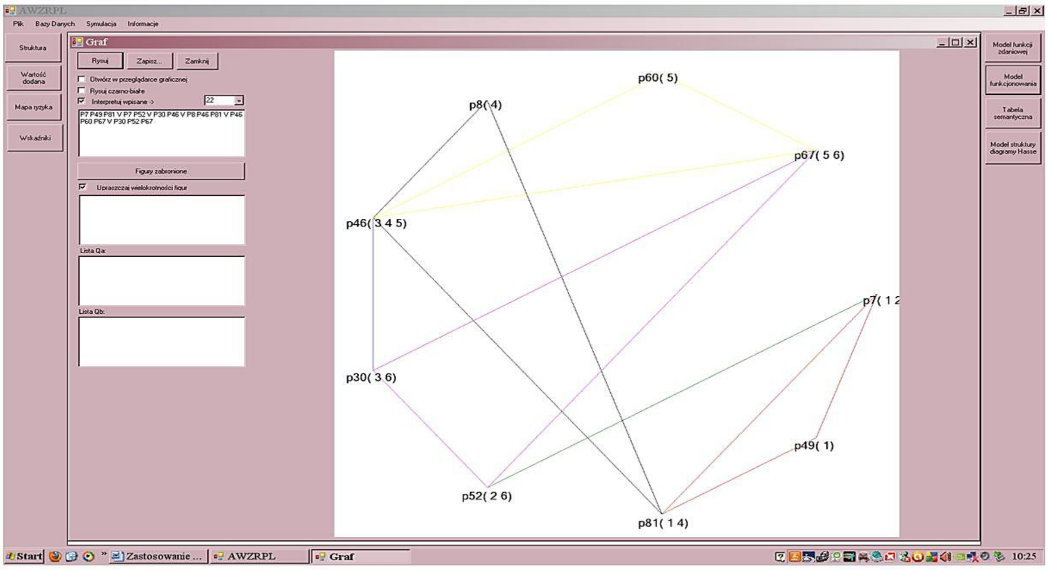

Figure 4. the operating model ψ_a of the propositional function ZP_x
(*source: own study*)

If we omitted the characterization principle then searching for the optimum Hasse diagram for the considered function would require analysing 3! * 2! * 2! * 3! * 3! * 3! = 5184 possible variants of Hasse diagrams. Even so, it would be impossible to find an optimum diagram because of forbidden figures in form of the Q^A and Q^B submodels present in the graph ψ_a model.

It is appointing the prohibited figures of the type Q^A and Q^B that is enabled by the module "operating model of the ADRM simulator". For the ZP function there were identified three prohibited figures of the type Q^A and one prohibited figure of the type Q^B . Next vertexes of the prohibited figures Q_1^A, Q_2^A, Q_3^A, represent propositional variables, which appear in conjunctions in the fixed order and form loops graphically (see Figs. 5-8).

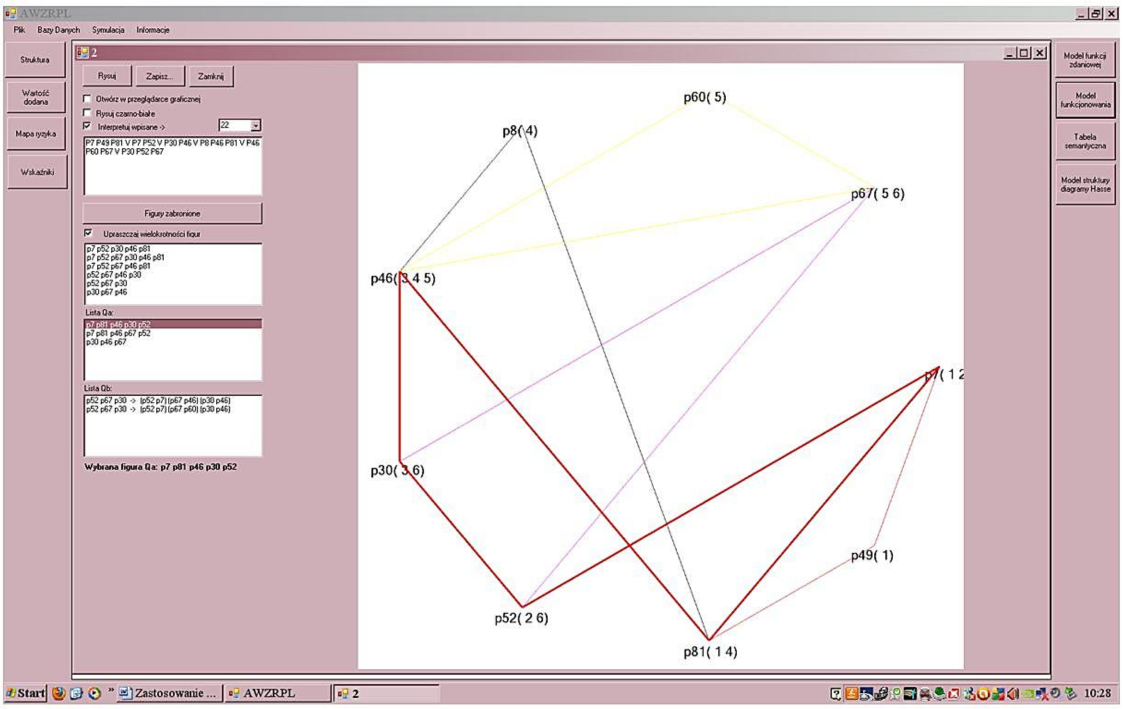

Figure 5. The graph model of functioning of the function ZP_x
with the marked prohibited graph figure of the type Q_1^A
(*source: own study*)

The formal record of the prohibited figure Q_1^A: $Q_1^A = \{P_{30}(3,6), P_{52}(6,2), P_7(2,1), P_{81}(1,4), P_{46}(4,3)\}$

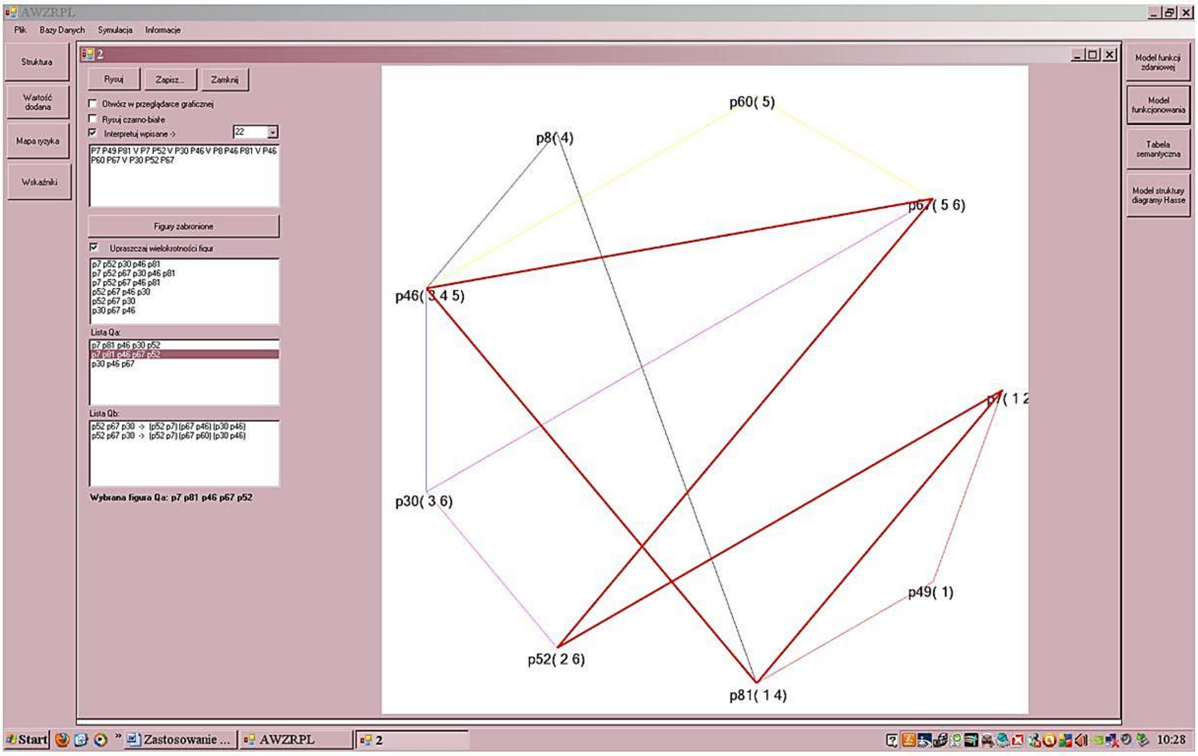

Figure 6. The graph model of functioning of the function ZP_x with the marked prohibited graph figure of the type Q_2^A (*source: own study*)

The formal record of the prohibited figure Q_2^A : $Q_2^A = \{P_{67}(6,5), P_{46}(5,4), P_{81}(4,1), P_7(1,2), P_{52}(2,6)\}$

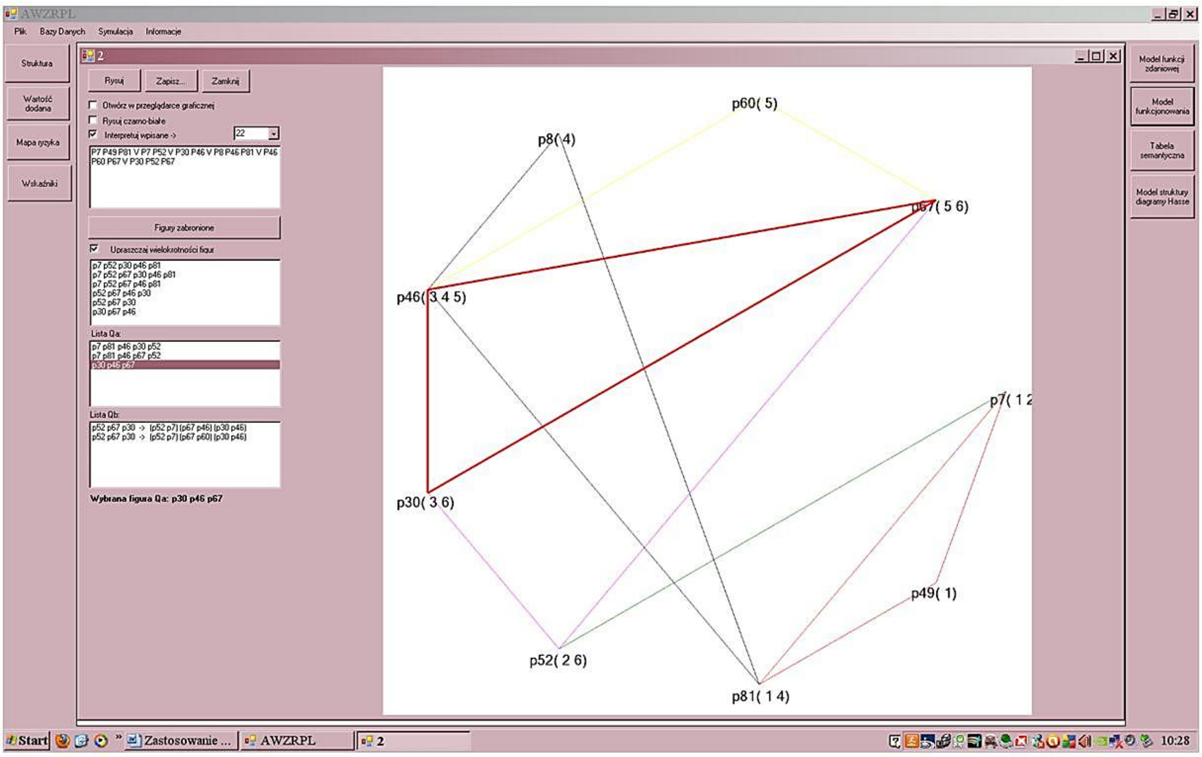

Figure 7. The graph model of functioning of the function ZP_x with the marked prohibited graph figure of the type Q_3^A (*source: own study*)

The formal record of the prohibited figure Q_3^A : Q_3^A: = {P_{30}(3,6), P_{67}(6,5), P_{46}(5,3)}

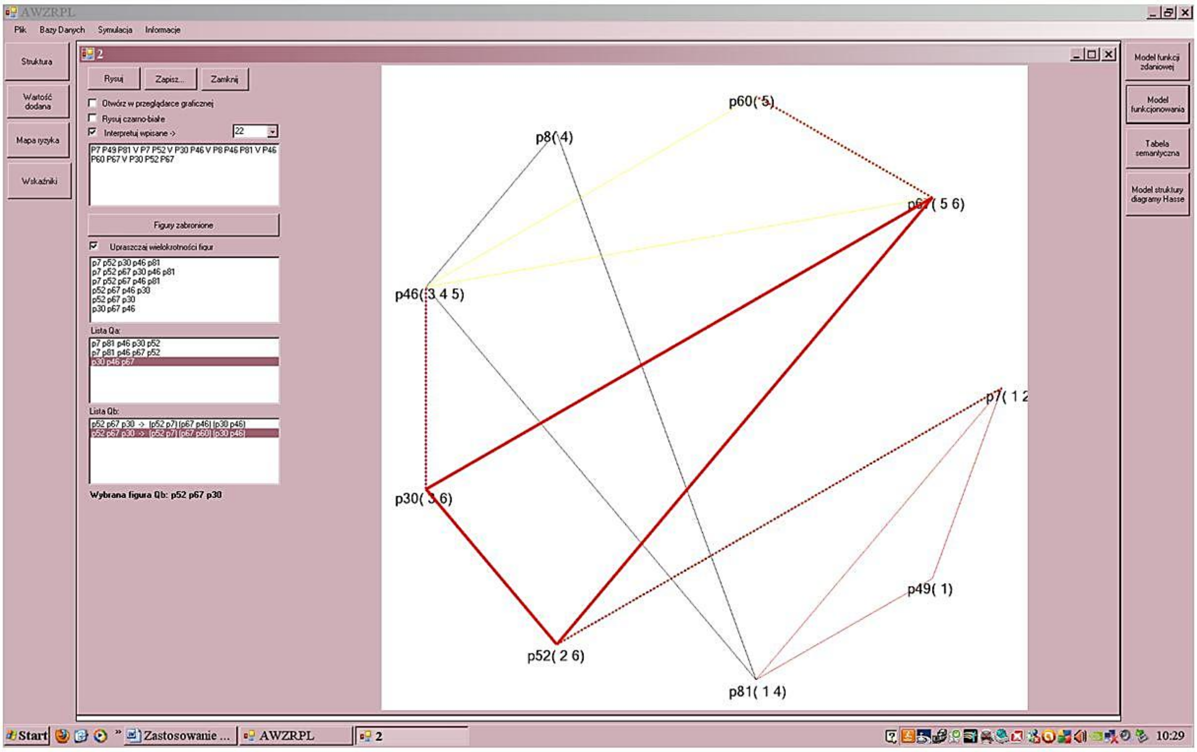

Figure 8. The graph model of the propositional function ZP_x
with the marked prohibited graph figure of the type Q_1^B
(*source: own study*)

The second type of the prohibited figure is the QB figure, which is a graph submodel recorded in the form of the triangle with hanging vertexes. The analysed function also contains one figure of this type marked with the thickened line on the Fig. 8 and the hanging vertexes are marked with the broken line.

The formal record of the figure of this type Q_1^B:

$$Q_1^B = \{\{P_{30}, P_{52}, P_{67}\}\{P_{30}, P_{46}\}\{P_{52}, P_7\}\{P_{67}, P_{60}\}\}$$

The presence of this type of submodels in the graph representation of the propositional function was noticed by V.A. Gorbatov. Admittedly, it is in the analysed case that we deal only with the four "images", but the possibility of their identification and their split spares many hours of work and analyses of 5184 possible variants of Hasse diagrams, which this function has.

It is for splitting the prohibited figures, which appeared in the graph representation of the analysed propositional function that a semantic decision table was built. In the first line of the table, there were entered propositional variables, which appeared in all identified prohibited figures. Whereas the prohibited figures were entered in the first column. In next lines, we mark with the digit 1 the propositional variables as a vertex in the prohibited graph figure, which appeared in the given prohibited figure.

In the ADRM simulator, the semantic decision table is drawn on automatically based on the entered function. After having chosen the module "the semantic decision table", it is in the window on the left of the screen that a propositional function is shown, and on the right the semantic decision table adequate for it (see Fig. 9).

We choose the minimal subset of propositional variables, which will cause the elimination of all prohibited figures taking into account the frequency of the presence of the propositional variable in the prohibited figures (the largest number of "1" in the column of the semantic decision table), as well as it is from a point of view of the ADRM of logistic processes that we choose these propositional variables out of alternative solutions, which represent the risk factors of the lowest probability (frequency) of presence and of the lowest cost of potential effects of appearing.

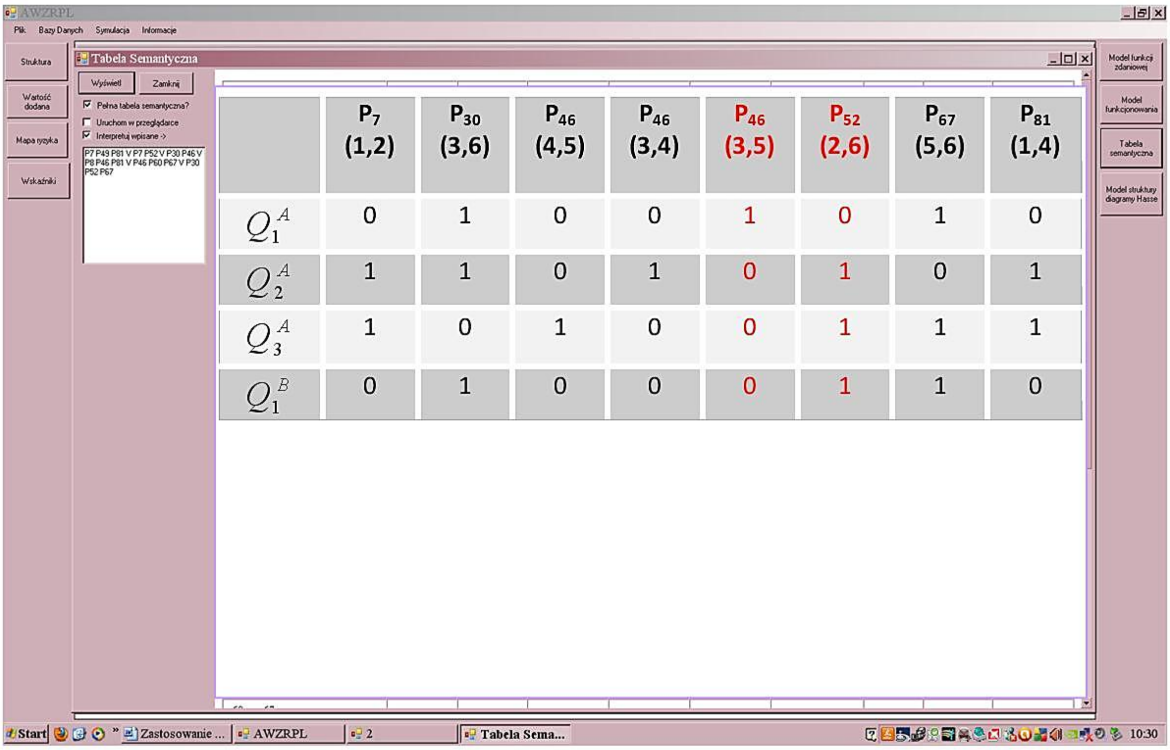

Figure 9. The semantic decision table of the function ZP_x
(*source: own study*)

It is in the analysed function that two pairs of variables enable splitting all prohibited figures:

- The first pair: the propositional variable $P_{30}(3,6)$, which will enable to split prohibited figures Q_1^A Q_2^A Q_1^B, and the propositional variable $P_{46}(4,5)$, which will enable to split the propositional variable Q_3^A.
- The second pair: the propositional variable $P_{52}(2,6)$, which will enable to split the prohibited figures Q_2^A Q_3^A Q_1^B, and the propositional variable $P_{46}(3,5)$, which will enable to split the propositional variable Q_1^A.

The choice of variables will condition the form of the new ψ'_a operating model, and hence the character of the ultimate Hasse diagram and the level of actual costs of marking out of risk factors in logistic processes, which translate into the level of the obtained value added. After taking into account both criteria for splitting, we choose variables $P_{52}(2,6)$ and $P_{46}(3,5)$. The propositional variable P_{52} is split by us in the second conjunction, whereas the variable P_{46} in the third conjunction (see Fig. 10).

As a result of splitting we receive a new operating model Fig. 10, which corresponds with the appropriate Hasse diagram, presented on the Fig. 11.

A new form of the function ZP'_x :

$$ZP_x (P_1, P_2,\ldots,P_{81})' = P_7\, P_{49}\, P_{81} \vee P_7\, P'_{52} \vee P_{30}\, P'_{46} \vee P_8\, P_{46}\, P_{81} \vee P_{46}\, P_{60}\, P_{67} \vee P_{30}\, P_{52}\, P_{67}$$

for which the new operating model ψ'_a takes the following form:

$$\Psi'_a = < M', R'_2, R'_3>$$

$$M' = < P_7, P_8, P_{30}, P_{46}, P'_{46}, P_{49}, P_{52}, P'_{52}, P_{60}, P_{67}, P_{81}>$$

$$R'_2 = \{P_7,P'_{52}\}_2, \{P_{30}, P'_{46}\}_3$$

$$R'_3 = \{P_7, P_{49}, P_{81}\}_1, \{P_8, P_{46}, P_{81}\}_4, \{P_{46}, P_{60}, P_{67}\}_5, P_{30}, P_{52}, P_{67}\}_6$$

Each of the risk factors selected for the analysis P_7, P_8, P_{30}, P_{46}, P_{49}, P_{52}, P_{60}, P_{67}, P_{81} includes information on the frequency (the probability) of appearances of risk factors as well as potential effect (measured with the maximum cost of removing the effects of the appearance of the risk factors). Taking into account the data of the E Company, these values were as follows – Table 1.

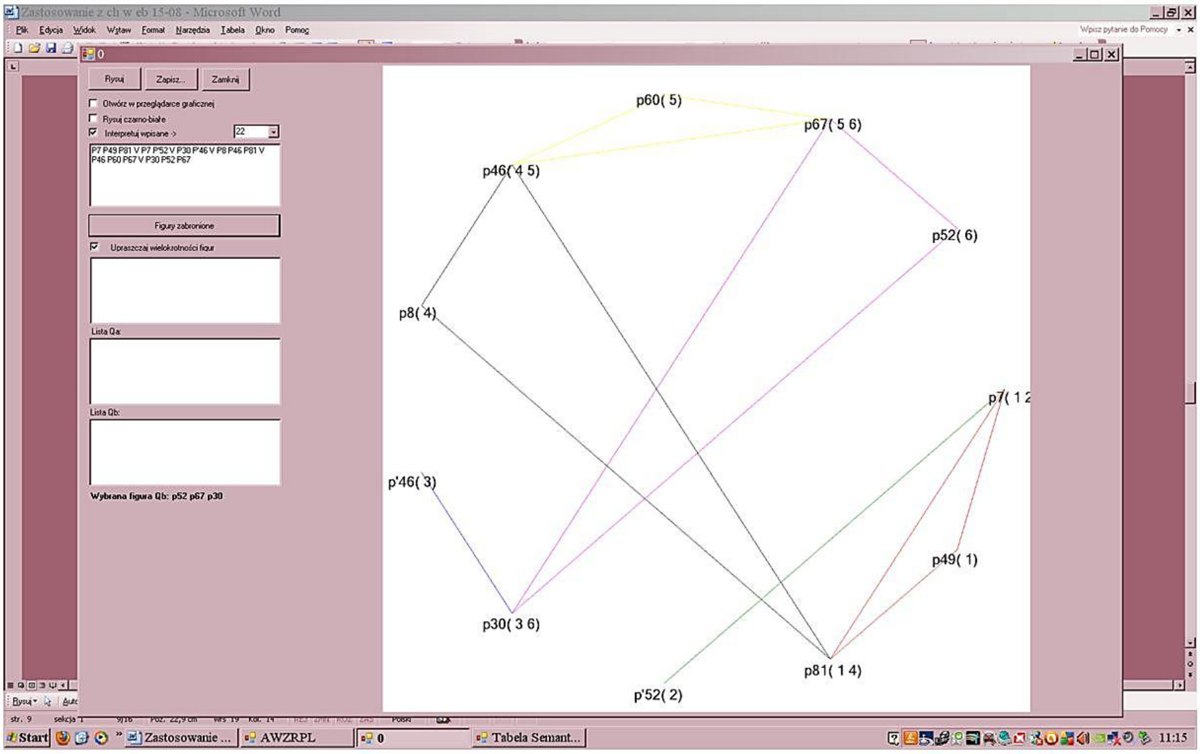

Figure 10. The new graph model of functioning of the ψ'$_a$ propositional function ZP_x after splitting the prohibited graph figures
(*source: own study*)

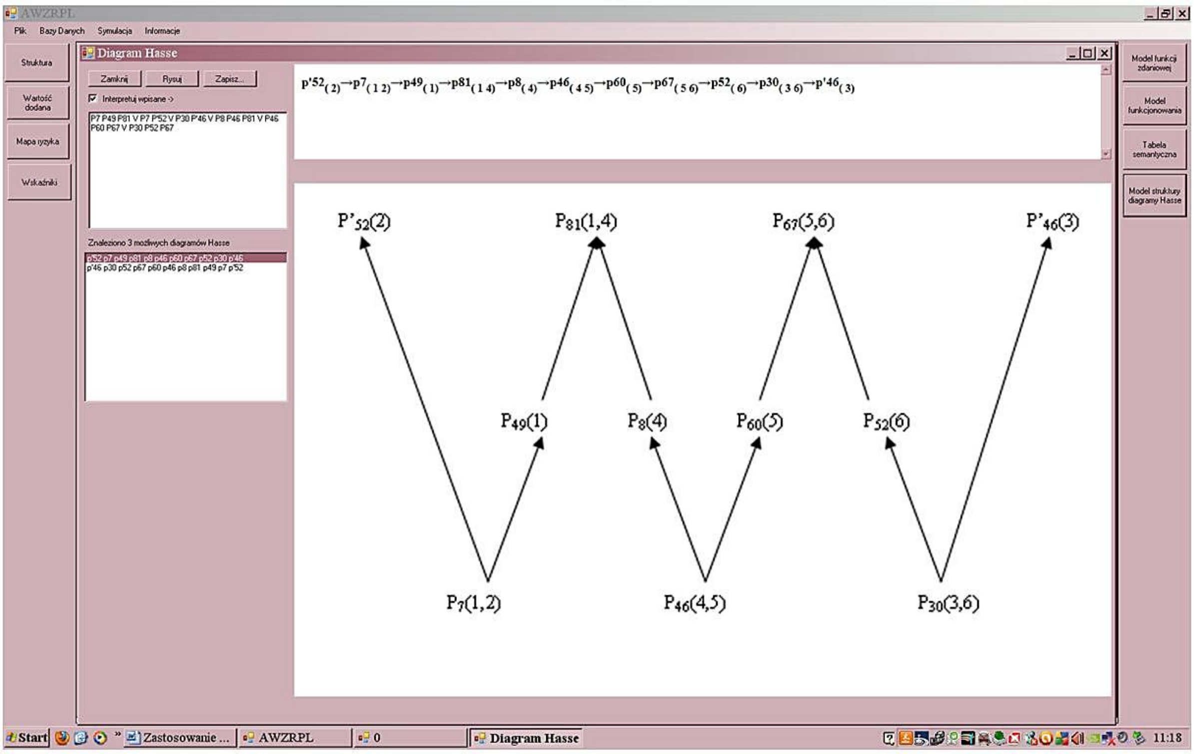

Figure 11. The structural model ψ'$_b$ of the propositional function ZP_x
(*source: own study*)

Table 1. The juxtaposition of the probability and the effect of appearing of risk factors in the function ZP_x
(*source: own study on the basis of the results of the questionnaire survey*)

the area of the risk factors appearance	propositional variable	2004		actual costs of individual risk factors (PLN)
		amount	max cost	2004
supply	P_7	16	840	13440
	P_{49}	14	478	6692
	P_{81}	23	199	4577
production	P_7	16	840	13440
	P_{52}	19	45	855
distribution	P_{30}	32	84	2688
	P_{46}	14	478	6692
transport	P_8	12	373	4476
	P_{46}	14	478	6692
	P_{81}	23	199	4577
storing	P_{46}	14	478	6692
	P_{60}	18	47	846
	P_{67}	19	74	1406
managing logistic processes	P_{30}	32	84	2688
	P_{52}	19	45	855
	P_{67}	19	74	1406
Σ total all-in costs of examined risk factors				**78022**

It is on this base that we can determine that the operating model includes information on all-in costs of the presence of risk factors in logistic processes, since it is data mapping the direct information from the company examined in the given period of time. While limiting to these factors, we can state that the value added of the company could be higher by about PLN 78 022. On the annual basis of the operations of the company listed on the Warsaw Stock Exchange, it seems not to be a large amount but we have analysed just a few risk factors here.

In fact, the costs of the presence of risk factors are most often higher than the ones, which are shown in income statements. It is for obtaining information on actual costs, which result from risk factors that the interpretation of the structural model is essential. On this basis we know that the replica of variables in the following form were obtained: P'_{46}, P'_{52} . It has it consequences in the cost accounting of risk factors present in logistic processes. It is in the Table 2 that the costs of risk factors were put together on the basis of the new ψ'_a operating model.

While comparing the total and actual costs of the appearance of risk factors (see Table 3), one can notice the importance of their correct calculation. After examining a small number of risk factors, the difference was more than PLN 7 000 - Table 4,what gives the preliminary idea of the scale of the phenomenon.

Table 2. The cost analysis of the results of removing individual risk factors for the chosen propositional variables - in the ψ'_a operating model of the ZPx function'

the area of the risk factors appearance	propositional variable	2004		real costs of individual risk factors (PLN)
		amount	max cost	2004
supply	P_7	16	840	13440
	P_{49}	14	478	6692
	P_{81}	23	199	4577
production	P_7	16	840	13440
	P_{52}	19	45	855
	P'_{52}	19	45	855
distribution	P_{30}	32	84	2688
	P_{46}	14	478	6692
	P'_{46}	14	478	6692
transport	P_8	12	373	4476
	P_{46}	14	478	6692
	P_{81}	23	199	4577
storing	P_{46}	14	478	6692
	P_{60}	18	47	846
	P_{67}	19	74	1406
managing logistic processes	P_{30}	32	84	2688
	P_{52}	19	45	855
	P_{67}	19	74	1406
σ total all-in costs of examined risk factors				**85569**

Table 3. The comparison of all-in costs and actual costs of the removing effects of the appearance of risk factors

balance	
all-in costs	actual costs
78022	85569
difference: **7547**	

The consequences of underestimating the costs associated with eliminating the effects of undesired events are visible in income statements of each of examined company.

There are also cases of underestimating costs of risk factors, what will be illustrated by the second example. This time, we choose 6 of 81 risk factors out of the data of the E Company, which are characterized by the highest cost of removing the effects of their appearance. They include: promptness of deliveries (P_7), breakdowns of machines and devices (P_{20}), not keeping order fulfilment time (P_{46}), breakdowns of cars (P_{53}), possession of unnecessary inventories (P_{63}), problems in the flow of information (P_{67}). The ZP_y propositional function takes the following form:

$$ZP_y (P_1, P_2, \ldots, P_{81}) = P_7P_{53}P_{63}P_{67} \vee P_{20}P_{53}P_{63}P_{67} \vee P_{46}P_{53}P_{63}P_{67} \vee P_{53}P_{67}P_T \vee P_{63}P_{67}P_M \vee P_{67}P_{Zl}$$

It is for saving the correctness of the modelling both in management studies and Boolean algebra (there has to remain 6 conjunctions because of the number of the considered logistic areas, however when viewed from algebra of logic, some conjunctions are included in other ones, what would require the implementation of the corresponding mathematical operations and losing the number of areas), that the apparent propositional variables P_T, P_M, P_{Zl} were entered into appropriate conjunctions, (representing neither costs nor the frequency of risk factors appearance - described in the mathematical way).

It is checking the possibility of obtaining of the logical structure (the ψ_b model) in the form of the Hasse diagram that we begin with the analysis of the function, which will enable the development of an operating model (the ψ_a model).

The resulting function is a logical product of two functions of the type:

$$[\alpha \vee \beta] \,\&\, [\gamma \vee \delta] = [P_{67}] \,\&\, [P_7P_{53}P_{63} \vee P_{20}P_{53}P_{63} \vee P_{46}P_{53}P_{63} \vee P_{53}P_T \vee P_{63}P_M \vee P_{Zl}]$$

where:

$[\alpha \vee \beta]$ - the first function P_{67}

$[\gamma \vee \delta]$ - the second function $P_7P_{53}P_{63} \vee P_{20}P_{53}P_{63} \vee P_{46}P_{53}P_{63} \vee P_{53}P_T \vee P_{63}P_M \vee P_{Zl}$

It is for the first function $[\alpha \vee \beta]$ that the Hasse diagram is a single vertex marked as P_{67}. This vertex will be a beginning or an end of all branches of the Hasse diagram of the second function $[\gamma \vee \delta]$.

The second function $[\gamma \vee \delta]$ cannot be shown as a product of logic functions (decomposition of the product of the logical function) but it can be considered as a starting point for further analysis and construction of the ψ_a and ψ_b models. The function $[\gamma \vee \delta]$ can be presented as a logical sum (decomposition with regard to the logical sum of the function) of two functions in the form:.

$$[\gamma \vee \delta] = [P_7 P_{53} P_{63} \vee P_{20} P_{53} P_{63} \vee P_{46} P_{53} P_{63} \vee P_{53} P_T \vee P_{63} P_M] \vee [P_{Zl}]$$

The decomposition with regard to the logical sum of the function is not essential, however it greatly simplifies the process of searching for prohibited figures. It is thanks to the decomposition that all "false" prohibited figures are eliminated and the real ones Q^A and Q^B remain.

For the analysed function, the actions carried out, cause that a significant simplification of the function subjected to conversions with the characterization principle is completed. It is also much more easy to draw the ψ_a model obtained directly from the function $[\gamma \vee \delta]$.

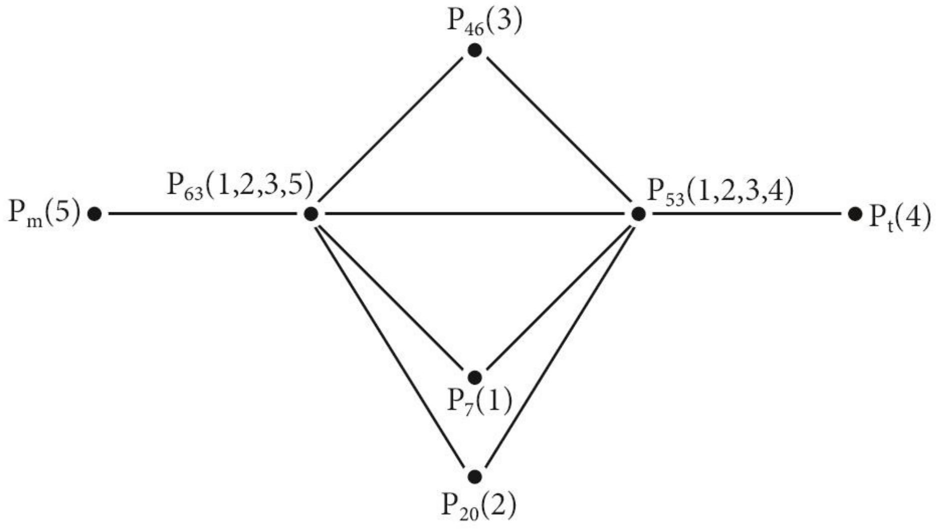

Figure 13. The drawn manually ψ_a operating model
(*source: own study*)

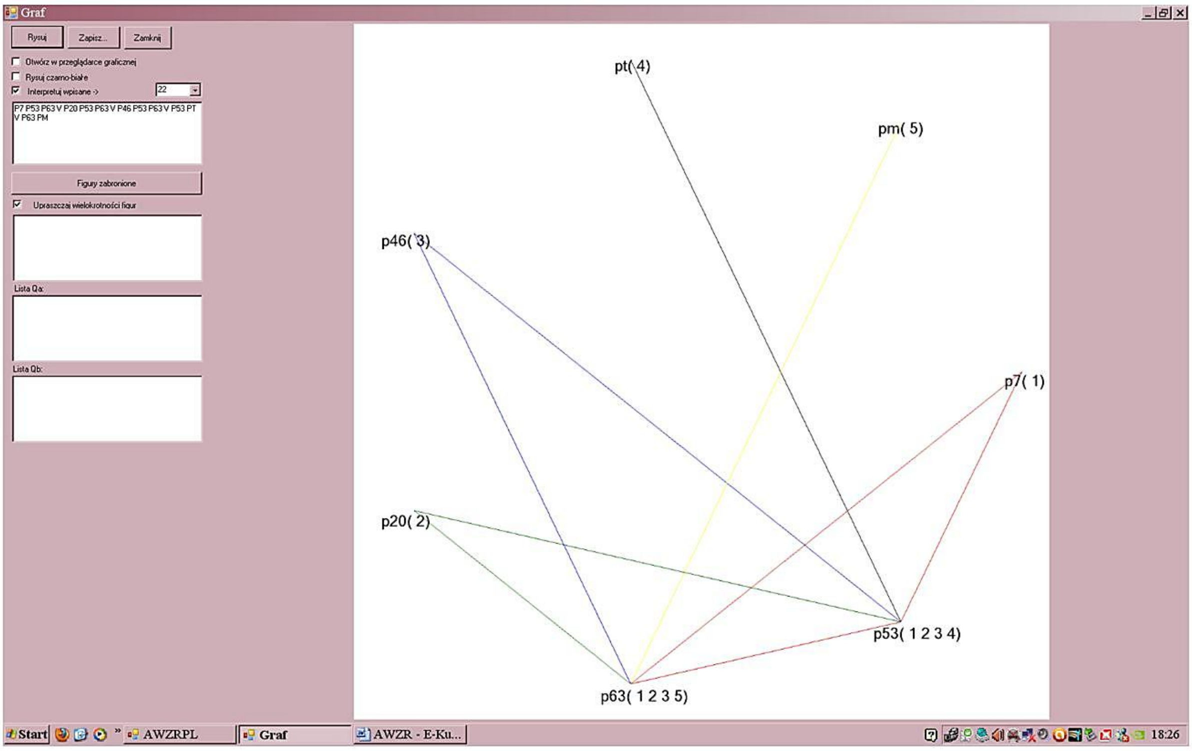

Figure 14. The ψ_a operating model obtained in the ADRM simulator
(*source: own study*)

It is on both figures that we can see that there is no prohibited Q^A or Q^B figure - which means that there is a possibility of drawing a correct Hasse diagram without the need of splitting the variables (vertexes of the graph) of the model.

Thanks to the disintegration of the function [γ V δ] with regard to the logical sum, we obtain information on branches which will appear in the structural model. The full form of the base of the Hasse diagram - Fig. 15.

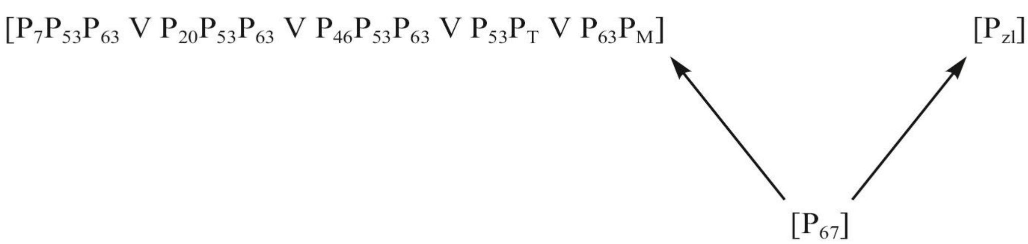

Figure 15. The full form of the base of the Hasse diagram
(*source: own study*)

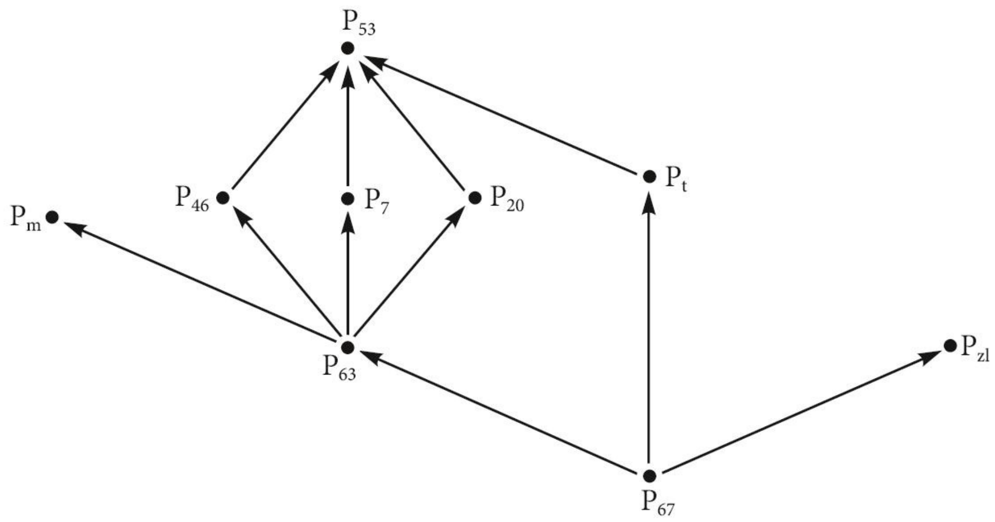

Figure 16. The full form of the Hasse diagram for the function ZP_y
(*source: own study*)

Table 4. Actual costs of the appearance of risk factors - The E Company
(*source: own study on the basis of the results of the questionnaire survey*)

the area of the risk factors appearance	propositional variable	2004		actual costs of individual risk factors (PLN)
		amount	max cost	2004
supply	P_7	16	840	13440
	P_{53}	17	85	1445
	P_{63}	12	47	564
	P_{67}	14	74	1036
production	P_{20}	15	1010	15150
	P_{53}	17	85	1445
	P_{63}	18	47	846
	P_{67}	14	74	1036
distribution	P_{46}	14	478	6692
	P_{53}	15	85	1275
	P_{63}	13	47	611
	P_{67}	14	74	1036
transport	P_{53}	15	85	1275
	P_{67}	19	74	1406
storing	P_{63}	17	47	799
	P_{67}	18	74	1332
managing logistic processes	P_{67}	18	74	1332
Σ total all-in costs of all risk factors				**50720**

Table 5. The real costs of the appearance of risk factors - The E Company
(*source: own study on the basis of the results of the questionnaire survey*)

propositional variable	2004		real costs of individual risk factors (PLN)
	amount	max cost	2004
P_7	16	840	13440
P_{20}	15	1010	15150
P_{46}	14	478	6692
P_{53}	15	85	1275
P_{63}	17	47	799
P_{67}	18	74	1332
Σ total actual costs of analysed risk factors			**38688**

Table 6. The comparison of all-in costs and actual costs of the removing effects
of the appearance of risk factors

balance	
all-in costs	actual costs
50720	38688
difference: **12032**	

Taking into account the total Hasse diagram based on the primal ZPy function, it will adopt the form as on the scheme from the Fig. 16.

As can be seen on the basis of the conducted analysis, the number of propositional variables of the operating model is 20, including 17 variables representing the determined value of the effect and the probability. It is on the structural model that there are 9 of them including 6 variables representing the determined value of the effect and the probability.

Taking into account the data analysed on the example of the E Company, the values were as follows - Table 4.

While limiting the analysis to the presented risk factors, we can state that the value added of the company could be higher by about PLN 50720. It is for obtaining the information on actual costs caused by the risk factors that the interpretation of the structural model is essential. The conducted decomposition of the propositional function is tantamount to showing the possibility of limiting the scope of the influence of risk factors by introducing appropriate proceedings and anticipation measures. As a result of the executed decomposition of the propositional function, the number of propositional variables was successfully reduced, i.e. the scope of the influence of some risk factors. The actual cost of the presence of the analysed risk factors in logistic processes are shown in the Table 5.

While comparing total and actual costs of the appearance of risk factors, one can notice how important their correct calculation is (see Table 6).

5 Conclusions

In summary, while interpreting the results of the conducted analysis according to the characterization principle, one should take following information into consideration:

- the all-in cost is obtained by aggregating the costs of all propositional variables present in the function,
- the maximum actual cost is a sum of costs of all propositional variables including the necessary replicas of variables resulting from splitting,
- the minimum actual cost is obtained if the branches of the Hasse diagram are overlapping: that means

that a reduction in propositional variables is taking place so it is obvious cost reduction.

The application of the characterization principle to the ADRM parameterization of logistic processes is associated mainly with showing actual costs, in fact incurred, in relation to the presence of the determined risk factors in logistic processes

The analyses conducted in experiments showed that actual costs of the presence of risk factors were as a rule higher than the ones included in financial results. It was in the studies carried out in the E company that there were noticed 81 different risk factors concerning logistic processes, which allowed to demonstrate that actual costs of the presence of risk factors exceeded all-in costs shown in the profit and loss account (even though other result was achieved for 6 chosen factors).

It is not including actual costs of the presence of risk factors that can significantly affect the creation of value added translating into the conditions for the functioning of the company on the market.

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WHAT IS INNOVATIVENESS: LITERATURE REVIEW

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Abstract: For decades what has been heated are debates on topics such as: which country is the most competitive? What is the best country to live in?. However, it may be disputable whether results of these debates have practical outcomes. It is arguable whether is it clear what constructs are in fact discussed, how to measure their level, and how to draw conclusions from such studies. This paper addresses aspects relevant to innovativeness – interpretation, measurement, accuracy and practicality. This paper shows that despite of very abundant literature on the subject, the prime tangible effect deals with various rankings of countries for public relations purpose rather than it provides a policy setting directions.

Keywords: competitiveness, innovativeness, indicatoring innovativeness, efficiency, measure of efficiency.

1 Introduction

Aspects of competitiveness and innovativeness are currently probably among the most frequently exercised conversations relating to discussions about economic progress and prosperity. Numerous studies highlight the crucial importance of innovation to economic development and well-being (e.g., McArthur & Sachs [45], Porter [57], Rutten & Boekema [60], Blanke et al. [9], TEP [69], Lööf & Heshmati [42]). It is accepted that one must be innovative in order to be competitive. It should be noted though that innovation can be interpreted in different ways (FM [23], OM [56], Rogers [59]). Various interpretations of innovation make for an imposing obstacle when researching this subject. As a consequence the same is true of the notion innovativeness, along with the recognition of means that enhance its levels. Since innovativeness is considered to be a complex issue, and its measurement is not possible within the framework of accepted definitions of innovativeness, indicators and indexes are used in order to "quantify" this construct (e.g., Dosi et al. [17], Archibugi & Coco [4], IUS [34], Sajeva et al. [62], Freudenberg [26], Saisana & Tarantola [61], Katz [37, p. 893], Arundel & Hollanders[5], Schibany & Streicher [65]). This renders possible to "measure" levels of innovativeness, and rank countries with respect to their dedication to innovativeness (e.g., IUS [34], Sajeva et al. [62], Hollanders & Van Cruysen [32], Arundel & Hollanders [6], Nasierowski [51], [52]). The results of this activity may be indicative of organizational, legal, social, and political means and arrangements conducive to augmentation of innovativeness. These arrangements can be discussed within the scope of the concept of National Innovation Systems (e.g., Dahlman [15, p. 541], Dosi et al. [17], Freeman [25], Lundvall [44], Nelson [55], Shariff [68], Nasierowski [53]). However, when researching the subject "innovations", each of the steps from invention (innovation) to NIS, is punctuated with lack of precision, somewhat denotes a type of a discussion which started, yet has not produced a conclusion.

This paper intends to review the current stock of experience with interpretation and assessments of innovativeness. First, various perspectives to innovativeness are explored. Then, aspects of indicatoring (measurement) of innovativeness is reviewed, along with examination of the practicability of such attempts. The concluding section provides some suggestions for further studies. As well, it is explained why addressing these questions is warranted from practical and theoretical viewpoints.

2 Concepts of innovativeness revisited

One of the problems relevant to research on innovativeness is a difficulty to establish a precise definition for the following constructs: innovation, invention, creativity, and entrepreneurship: definitions that would allow quantification of these constructs. Scholarly discourse on these definitions has created a dizzying array of differing and sometimes contradicting explanations. Some attribute this state of affairs, at least in part to miss-definitions, or misinterpretations of what above mentioned constructs denote (e.g., Rogers [59]; Seng

Tan [67, p.1]). There seems to be agreement on considering innovation to be a novelty applied to something which already exists. The disagreement arises as to whether the change should be new to the market in general or only to a particular company (e.g., Välimäki, et al. [70]). The former, denoted for the purposes of this discussion as the Frascati [23] approach suggests that innovation is rooted in notion of novelty in global terms. These novelties are assessed indirectly by the level of various educational attainment statistics (EIS [20], KAM [36], R&D expenditures EIS [20], IUS [34]), and patent counts (e.g., Grilliches [29], Khan & Dernis [39]). The latter, the Oslo Manual (OM [56]) approach, takes a more micro perspective. It deals primarily with implementation and adaptation of solutions, and is oriented on a practitioner's viewpoint. This approach conceptualizes innovation as an application for commercial purposes.

Inventions often originate as a result of systematically undertaken Research and Development (R&D) activities. The following is a definition offered by the United Nations, which is also accepted by OECD in the Frascati Manual: "R&D is a creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications The basic criterion for distinguishing R&D from the rest of Science and Technology is that there is an appreciable element of novelty" (FM [23, § 63]). "Technical innovation activities are all of the scientific, technological, organizational, financial and commercial steps, including investments in new knowledge, which actually, are intended to, lead to the implementation of technologically new and improved products and processes (FM [23, p. 18]), and that are crucial to a company's survival (e.g., Jamison and Hård [35]). From the Frascati perspective, innovations are those solutions implemented in technologically new products / processes, or to products/processes, subject to significant technological improvements, that exhibit characteristics of novelty.

When such interpretations of innovation are accepted, then the majority of SMEs do not qualify as being innovative. These types of enterprises mainly imitate and adopt solutions. It is a very sound business concept. Next, inventiveness is only one element in the innovation process. R&D activities (leading to inventions) are only initial stages of the innovation process, which can be described in many different ways (e.g., Kline & Rosenberg [40, p. 289], Betz [8, Chapter 1-2], Nasierowski [54]). The concept of novelty in global terms is not emphasized in these models, and hence a weakened interpretation of novelty and innovation can be adopted. Innovations in an enterprise can be defined as an economic decision made in order to carry out tasks related to taking advantage of emerging market opportunities, or to preventing threats from materializing. Such decisions are often of strategic nature. They may have consequences for the competitive position of the company and to all aspects of its functioning; in short, they may bring profits. A similar interpretation is advocated by Oslo Manual [56], where the minimum requirement for something to be termed an "innovation" is for the product or process to be new or substantially improved for the specific company.

Schumpeter [66] defines the economic phenomenon of innovation as a process that takes an invention and develops it all the way to a marketable product or service that changes the economy. It can be conceptual or perceptual, should be related to opportunities, focused, and can be breathtakingly simple (Drucker [18]). Innovation can also be interpreted as a process specific to a period of time or particular region, which means that the introduction of an "old technology" to the region, with no previous exposure to this technology, is also an innovation. For example, Sajeva, et al. [62, p. 7] define innovation as "the process leading to the adoption and diffusion of new technologies, aimed at creating new processes, products and services. While the term adoption represents the final stage of an invention, diffusion focuses on the supply of new goods and services to the customer. In this context, innovation is the method to achieve competitiveness in the framework of the revised Lisbon agenda." Such view is also consistent with the Europe2020 Strategy.

Although such interpretations enhance discussions on innovativeness, the quantification of innovativeness or level of involvement in new activities remains a perplexing, multidimensional, concept. One can advocate an indirect means for the measurement of innovations. For example, levels of productivity, employment, revenues, or the betterment of competitive position can be used to measure innovativeness. Further measures may include the examination of distinctive competencies, or of quality. Such indicators, however, depend on the context of operations, market conditions, actions undertaken by competition, economic and political situations in the region, reputation of the company, and customer loyalty. These may all have a strong impact on results of "indicatoring" of innovation. Quantification of these processes is almost impossible in light of diversity of possible contextual factors. We deal with very dynamic systems, and "many of their properties emerge from interactions among the entities in them" (Katz [37, p. 893]). Interrelationships between and among these factors of innovativeness are not documented, and the measurement of innovation processes may fail to provide evidence regarding casual relationships.

Another troubling issue in the study of technological change is differentiating innovation from creativity. Innovation can be defined as an output (product, device, theory, etc.) that is somewhat new to the place, time, or purpose of its application. Innovation occurs as a result of successful implementation of creative ideas within an organization. Creativity, on the other hand, is the development of a novel and useful idea in any domain and is a seed for all innovations (Amabile [3]). Innovation is always creative but not all creativity is innovative. "In this view, creativity by individuals and teams is a starting point for innovation: the first is a necessary but not sufficient condition for the second". In short, creativity is a manifestation of a drive to shape an opportunity, whereas innovation is an attempt to apply this opportunity practically. Creativity is a process, which may not lead to implementation. To that end, identification or development of creative ideas and an ability to implement them are among the most important abilities of successful entrepreneurs.

For many practitioners "innovation refers to the development and improvement of products and processes arising from the exchange of knowledge among firms and other players in their environment" (CEDO [10], p. 2). Such interpretations stem from the concept advocated by the Oslo Manual (OM [56, § 131]), where a minimum requirement of innovation is for a product or a process to be new (or substantially improved) for the specific company: it need not be new in global terms. Thus, innovativeness deals with implementation of new solutions in the place or for the purpose, for which these have not been used earlier. Some public institutions also take a similar micro/practitioner's approach. For example, the Atlantic Canada Opportunities Agency (ACOA) recognizes the fact that innovation means different things to different people. In their terms, innovation is "a process through which economic value is extracted from knowledge through the generation, development, and implementation of ideas to produce new or improved products, processes, and services. Innovation encompasses much more than R&D or technological change. Innovation makes knowledge useful and turns it into wealth and prosperity" (ACOA [1, p. 8]).

It has been observed, that several items from the composite indexes, that may relate to the notion of innovativeness, deal primarily with inventiveness (e.g., on the Input side - expenditures on R&D and S&E graduates, or on the Output side - patents and trademarks). Thus, these indicators fall more towards Frascati interpretation of innovations (hence inventions) (FM [23, § 21 and 63]), quite a difference from innovations as interpreted by Oslo Manual (OM [56, § 131]). Consequently, it is arguable, whether these common composite indexes serve the needs of practitioners oriented towards the interpretation of innovations of enterprises aimed at improvement of economic prosperity at a "shop floor level" (Drucker [18]), or are primarily a manifestation of pro-innovation policies and mechanisms at the macro-economic level.

Further difficulties lie awaiting the researchers when they try to formulate plans for stimulating innovativeness and creativity, as well as entrepreneurship enhancement, along with attempting to improve economic performance of firms. And as if this is not enough, differences regarding interpretations are further amplified when micro and macro-economic perspectives are taken into account. It is observed that two perceptions of innovativeness can be identified; they refer to the same phenomenon, though from varying perspectives. One deals with a macro-economic view, suitable for big inventive companies, and levels of innovativeness are measured by composite indexes. The second perspective is more "shop-floor" oriented and deals with problems of changing ideas into commercial success. The first is leaning towards inventiveness, the second towards commercialization. Micro- and macro- perspectives are somewhat different 'worlds' – explained by state policies and international competitiveness determinants on one side, and a drive to increase competitive position and profits of an enterprise on the other. These two 'worlds' coexist, and more coordination of their principles and related activities may bring positive results. It would be incorrect to attempt to discuss the two as the same phenomena, and there is a need to identify means to bridge the gap between 'macro' and 'micro' perceptions and interpretations of innovation (Nasierowski [51], [52] and [53]). Hence, a comparison of concepts of innovativeness from the viewpoint of macro-economic indicators (e.g., as expressed by the EIS [20]/ IUS [34]), with opinions/perceptions of entrepreneurs that will provide a micro-economic perspective to the problem (Drucker [18], INNO [33]) is warranted. These considerations are expected to aid in finding better means to assist companies in enhancing their performance, thus contributing to economic progress at the macro-economic level.

The European Commission (IUS [34]) adopts a comprehensive approach to the definition of innovativeness and attempts to combine both macro- and micro-approaches. The term innovation not only describes innovation as an invention or technological improvement, but also includes the implementation of new ideas, processes and methods for leveraging existing ideas, technologies or inventions. Discussion is no longer limited to products, processes or technologies (e.g., Kedia & Bhagat [38]), or spin-offs (Arundel & Hollanders [6, pp. 4-10]), but also focuses on an overall replication of solutions that have been used somewhere else, or used for a separate purpose. The term innovation not only describes innovation as an invention, or a technological improvement, but also includes in its scope the implementation of new ideas, processes and methods for leveraging existing ideas, technologies or inventions further.

Thus, under the specific constraints, intuitive understanding of the concept "innovativeness" may be necessitated, though it may affect the precision of discussion about this concept. This situation is quite similar to psychological studies, where the vacuum of a sharp definition for intelligence is pragmatically filled by equating intelligence with IQ tests results. The researches of innovativeness face similar dilemmas of imprecision, as psychologists with definitions and interpretations of intelligence. The value of IQ is considered to be an objective measure. However, because intelligence is near impossible to precisely define, controversies surround the IQ tests. There is a debate about what exactly they do measure, and whether or not they indeed measure any objective value. In order to avoid fruitless quests by trying to define the exact meaning of intelligence, some psychologists accept that "intelligence is the phenomenon measured by IQ tests". Consequently, researchers of innovativeness may be forced to accept that innovations are what composite indexes of innovativeness indicate.

3 Indicatoring innovativeness

Assuming that definitions of invention, innovation, innovativeness are accepted, the next step in the discussion on the subject may deal with identification of indicators/indexes that will assist in measuring levels of innovativeness. Results of such "measurements" will allow a more quantitative discussion on available means for improvement. Some frequently referred to indexes are described below.

- The Growth Competitiveness Index (GCI) as published in the Global Competitiveness Report is based on three "pillars"(McArthur & Sachs [45]):
  - macroeconomic environment – assesses the stability of macroeconomic situations (e.g., through a tight monetary policy, low inflation) (macroeconomic stability, government waste, and country credit rating sub-indexes),
  - institutions – assure a favorable climate for long-term economic and business activities (e.g., contracts, law, and corruption sub-indexes), and,
  - technology – captures features of technological progress (innovation, ICT, and technology transfer sub-indexes).

  These three sub-indexes are then combined to calculate the overall GCI.
- The Knowledge Economy Index (KEI) of the World Bank is prepared based on the Knowledge Assessment Methodology (KAM) (e.g., Chen & Dahlman [12], KAM [36]), and highlights the importance of knowledge for long-term economic growth. Some 80 data series are grouped into: performance indicators; economic incentives; institutional regime; innovation system; education and human resources; information infrastructure.

  This information forms the basis for identifying four sub-indexes, emphasizing the use of:
  - existing and new knowledge and the flourishing of entrepreneurship,
  - an educated and skilled population to create, share, and use knowledge well,
  - a dynamic information infrastructure to facilitate the effective communication, dissemination, and processing of information,

- an efficient innovation system of firms, research centers, universities, consultants and other organizations to tap into a growing stock of global knowledge, to assimilate and adapt it to local needs, and to create new technology.

- The Human Development Index (HDI) is prepared within the United Nations Development Program, and is a "composite index measuring average achievement in three basic dimensions of human development – a long and healthy life, knowledge and decent standard of living" [30].
- The World Competitiveness Yearbook Index (WCYI) is prepared by IMD. Its objective is to analyze the facts and policies that shape a nations ability to create and maintain an environment of value creation for its enterprises and more prosperity for its people (WCY [72]). Based on 312 criterion, including data from various sources and an annual Executive Opinion Survey, there are four categories:
  - economic performance, which measures the macro-economics of the domestic economy,
  - government efficiency, which evaluates the extent to which government policies are conducive to competitiveness,
  - business efficiency, which assesses the extent to which enterprises are performing in an innovative, profitable, and responsible manner,
  - infrastructure which denotes the extent to which basic, technological, scientific and human resources meet the needs of business.
- The European Innovation Scoreboard / Innovation Union Scoreboard (an influential concept in the EU countries) is sponsored by the European Commission. Some 24 (26) indicators are used in order to create the EIS / IUS Index. These indicators are arbitrarily grouped into scales (categories), and classified as:
  - inputs (human resources, finance and support, firm investments, throughputs); and,
  - outputs (innovators, economic effects).

Each composite index consists of sub-indexes, where all items are equally weighted. This methodology may be challenged for correctness in terms of selecting (and grouping) indicators: numbers should indicate the number and nature of the factors that describe the idea. Moreover, several items are highly correlated – they carry the same information with regard to statistical significance of results (and country rankings) - thus some information is redundant. This methodology, in principle, is characteristic of all composite indexes presented.

Each studied index captures some information related to economic improvement. Since these items are correlated, it should be asked which ones act as stimuli for the development of other ideas. It can be asked whether many indicators are needed in order to measure innovativeness? and whether a compressed index of innovativeness can be constructed? Furthermore, with quite limited number of observations (countries) and many variables a non-parametric tests of efficiency cannot be done. Thus, a number of variables should be compressed. Certainly, a "compression" produces a trade-off between notions - index as a policy making drive versus index as a platform for ranking purpose.

Composite indexes use a variety of indicators (data series) to "measure" innovativeness. In such a way, they specify which items of economic performance may contribute to the enhancement of innovativeness. This may provide policy formulation related suggestions for governmental agencies for example. Inherently, however, an assumption is made that some 'policies', as measured by innovativeness indicators, will produce similar results irrespective of specific context in various countries. This may not be a correct assumption.

Freudenberg [26] provides a fairly extensive overview of composite indexes of country performance related to economy, environment, globalization, society, and innovation / technology. These indexes include, for example, the Growth Competitiveness Index (GCR [27]), the Knowledge Economy Index (Chen & Dahlman [12]), the Human Development Index (HDR [30]) and the World Competitiveness Report Index (WCY [72]). Composite indexes are used in a variety of economic performance and policy areas. Such indexes integrate large amounts of information into easily understood formats and can be manipulated to produce desired outcomes. Despite this, there are several methodological problems regarding the creation of composite indexes (Saisana & Tarantola [61]). Quandaries occur when examining the accuracy and reliability of these indexes. Problems of missing data are imminent, along with the question of index sensitivity to the weighing of indicators and their aggregation (Freudenberg [26, p. 5]).

Composite indexes are intended to measure different phenomena: however, they produce similar results in terms of ranking of countries: thus, they may measure the same aspects. The need and/or usefulness of such diversity among indexes is questionable. Despite being created with different intentions, and using varying series' of data for calculations, these composite indexes actually produce similar results when raking countries (Mirchandani [46], Nasierowski [47]). This occurs irrespective of whether they intend to measure level of innovative capability, competitiveness, productivity, level or wealth, or standard of living. There is a chance that a there are more simple means to measure innovativeness.

Albeit these problems exhibited by indexes of innovativeness, there has been a noticeable proliferation of composite indexes (e.g., Archibugi & Coco [4, pp. 179-181]). It should be noted that the preceding discussion does not negate the usefulness of these indexes. Rather, the results question the need for other indexes that replicate the rankings of alternate or better established measures.

4 About practicalities of indicatoring innovations

Even though diverse interpretations of creativity, innovativeness and entrepreneurship may enliven possible discourses about their nature imperatives and effectiveness, it does not help find a reasonable way to measure them. For example studies that make the tall claim of measuring innovation (or productivity of innovation generating units) by recording number of patents, publications, etc seem hollow and incomplete because they completely ignore the meaty qualitative dimensions of innovation, while excessively fixating on the quantitative dimensions. This leads one to advocate an indirect means for measuring innovation. We can measure innovation by evaluating factors such as productivity, employment, revenue or profit increase, improvement of competitive position, creating distinctive competencies, or quality (if such indicators can indeed be measured). Yet, these indicators depend upon a variety of factors such as the specific context of operations, market forces, actions undertaken by competition, economic and political influences shaping the particular region, company's reputation, and customers loyalty, all of which may significantly impact results of innovation measurements.

It is quite a task to measure the impact of innovation upon business performances given the insidious presence of market forces. Also quantification of these processes is virtually impossible taking into account diversity and numerous possible contextual factors. It is highly unlikely that companies will disclose information regarding their innovation related procedures, nor would they allow outsiders to observe their processes. Thus, the intimates of the relationship between these factors will not be documented. Moreover, measurement of innovation processes may fail to provide evidence regarding casual relationship, which additionally may be of a non-linear character.

It is at times accepted that composite indexes may serve as a policy setting mechanism (that has been also one of the objectives of the EIS / IUS approach). However, recommended innovation policies should not be considered as "an average" of responses from different sectors, by companies of different size, which operate within very different economic, political, and social context. An assumption that – "indicators have policy implications" – is difficult to endorse. Presented observations suggest that countries should adopt different innovation policies. Consequently, the power of indexes as a tool that sets direction for policy formulation is substantially decreased.

Problems arise when using composite indexes also due to the conceptual quandary between allocative efficiency ('are we doing the right things?') versus technical efficiency ('are we doing things the right way?'). Further dilemmas stem from problematic definitions and the various taxonomies used to measure the consequences of the output achieved (e.g., Seng Tan [67]).

5 About efficiency of pro-inovative approaches

Increases in innovation and the benefits that result from such an attitude are important factors in fostering economic activity and boosting competitive advantage. The vital role of innovation in national competitiveness is recognized by most nations. Knowing a nation's strengths and weaknesses allows a government to institute interventions aimed at fostering its innovation record. Therefore attempts to "measure" levels of innovativeness, along with assessment of efficiency / effectiveness of pro-innovative policies, have been undertaken. One may identify two basic approaches to estimate effectiveness:

- the first, probably the most popular now, where the level of innovativeness is determined as a sum, or a ratio, of inputs and outputs to the innovation processes. In such a case, one may expect, that the higher the input the higher the output, and hence the higher the level of innovativeness. This is the underlying assumption of the EIS / IUS approach, and its associated composite index of innovativeness – probably the leading approach to measure levels of innovativeness in Europe. This concept has been "developed by the European Commission, under the Lisbon Strategy, to evaluate and compare the innovation performance of its Member States" (EIS, [20, p. 3]),
- the second, where the efficiency of organizations (systems, approaches) is denoted with the use the "best practice frontier" concept: here the distance from such a frontier represents inefficiency - in other words the inability to produce maximum output from given inputs. This approach is linked to the effectiveness approach to National Innovation Systems, the line of thinking about the issue initiated by Arcelus and Nasierowski (Balazat & Hanush [7, pp. 202-203]).

5.1 Country rankings as a measure of efficiency

One of the main assumptions of composite indexes (and the EIS / IUS approach in particular), is that indicators that create the innovativeness index, should have practical implications. The level of innovativeness can be impacted by regulations and national innovation policies. This trend may also be rooted in recommendations of Aho Report [2] that suggests "a 4-pronged strategy focusing on the creation of innovation friendly markets, on strengthening R&D resources, on increasing structural mobility as well as fostering a culture which celebrates innovation". However, data series used in these composite indexes change almost every year. Consequently, there is no possibility of identifying whether policy changes have contributed to the improvement of desired operational outcomes.

The information content of EIS / IUS can be examined from the viewpoint of ranking countries against each other, and compared to other indexes that assess economic prosperity of countries. However, recommended innovation policies should not be considered as "an average" of responses from different sectors, or by companies of different size, which operate within very different economic, political, and social contexts. Thus, the assumption used in the EIS / IUS approach – "that indicators have policy implications" – is difficult to endorse. Results derived from the EIS / IUS reports present only a partial picture of the innovativeness of countries. This data focuses on a country's ranking, and whether they are a leading country, exhibit average performance, are catching up, or are losing ground. As was earlier outlined, it is recommended that emphasis be placed on the simplicity of composite indexes without compromising their explanatory power. Also, it is important that aspects of efficiency are addressed in a way which permits better modeling of EU policies to sectorial and regional specificity. Such ranking does not take specific economic and social conditions of the country into account, and emphasizes quantitative dimension of the issue – "the more the better". However, it is equally important to know whether or not resources available are used efficiently

It is reasonably clear from the preceding discussion that the methodological base given in EIS / IUS is not exempt from controversy. These reports give equal weight to each factor, thereby having the average of the factor loadings as the overall country measure from which to obtain the ranks. The issue of contention when assessing levels of innovativeness is the weight to assign to each factor in computing the overall score for each country. Yet: why each component enters the index with the same weight for all countries, regardless of whether or not the outputs and inputs themselves enter the computation equally weighted? There is the lack of evidence that items are equally important in the rankings. This implies, again, that the process of identifying the inputs and outputs required in the computation of the appropriate index of innovativeness makes the implicit assumption of all countries being equally efficient in the transformation of their inputs into their outputs.

A possible solution to this problem is to weigh each factor by the percentage of the total variance explained by the said factor and /or to compute the measure of efficiency on the basis of the factor loadings obtained through the principal component analysis. Even if this approach is used than still an important question remains unanswered: in practice, it is possible for two different countries to utilize totally different amounts of resources to produce an equivalent amount of outputs, without this difference being reflected in the index of innovativeness. Similarly, it is equally possible for two different countries to employ similar sets of resources and yet produce different output amounts.

This leads to the important issue relative to the assessment of the technical efficiency (EFF) of countries in the process of transforming inputs into outputs. From a micro-economic perspective, such issue epitomizes the concept of Paretto-Koopmans efficiency (Varian [71]), related to the ability of a country to minimize the number of inputs required to produce the maximum set of outputs possible. A country "is fully efficient if and only if it is not possible to improve any input or output without worsening some other input or output." (Cooper [14, p. 45]).

5.2 Measuring technical efficiency

While accepting the importance of innovative activities for economic well being of nations, it is warranted to examine the efficiency of turning inputs of innovativeness into outputs that enhance social welfare. Several studies on the efficiency of organizations (systems, approaches) use the "best practice frontier" concept. Here the distance from such a frontier represents inefficiency: in other words the inability to produce maximum output from given inputs. Parametric approaches (e.g., regression methods) are used to estimate parameters of technical efficiency. However, many elements, such as multicollinearity, model misinterpretation and measurement error, the use of multiple outputs, and omitted variables, can weaken the precision of these parameter estimates (Chapple et al. [11]). Consequently, it may be more appropriate to depart from a cursory examination of a ratio of inputs to outputs, and examine "best practice frontiers" from the viewpoint of contemporary economic concepts using the non-parametric DEA model in order to estimate the Farrell Input –Saving Measure of Technical Efficiency. This means that the measure of technical efficiency is examined as the greatest proportion of inputs which can be reduced and still produce the same output (Färe & Grosskopf, [21, p. 14]). Constraints of such an approach include the requirement of a specific ratio of observations (countries considered) to number of variables (indicators) used to describe the situation. In such a case the use of DEA is not possible: a more simplistic composite index is needed in order to evaluate the efficiency of national innovativeness efforts. Several papers have reported results related to the use of this approach (e.g., Nasierowski [47], [48], Nasierowski & Arcelus [49], [50], Hollanders & Esser [31]).

Two crucial characteristics of a country's production process have an important impact on the efficiency computations. These are returns to scale (RS) and congestion (CON), two key concepts of production economics (e.g., Cooper [14], Coelli et al. [13], Wei & Yan [73]).

RS deals with the rate of change in the inputs utilized, as compared, with the rate of change in the outputs obtained. Constant RS (CRS) occur, when the rate of changes in the inputs equals that of the output. Alternatively, if rates differ from each other, there is evidence of variable returns to scale (VRS). Another RS index is associated with the non-increasing returns to scale (NRS). The second characteristic, congestion, deals with the cost of disposing of unwanted inputs. The inefficiency arises from the fact that the presence of congestion requires the use of resources for the elimination of the undesirable inputs that would otherwise have gone to generate more outputs. "Evidence of congestion is present when reductions in one or more inputs can be associated with increases in one or more outputs - or, proceeding in reverse, when increases in one or more inputs can be associated with decreases in one or more outputs - without worsening any other input or output." (Cooper [14]). Examples of input congestion appear in Coelli, et al. [13, p. 195], among many others, in cases of government or union-based controls on the use of certain inputs. The literature employs the terms weak (WD) and strong (SD) disposability to denote whether evidence of congestion exists or not.

Some results of application such a procedure have indicated that (Nasierowski [51], [52]):

- To be efficient, the average country should cut down some volume of inputs utilized for the generation of the outputs and still produce the same level of outputs. Part of that inefficiency is due to scale and congestion problems.
- The average country's technological base is operating of the basis of decreasing returns to scale. Therefore, from an examination of those countries operating under a DRS technology, it is clear that their inefficiency is mostly scale related, with almost no congestion. A testable proposition of this state of affairs is that these countries are largely the heaviest investors in innovation over

time and that, at present, are at the decreasing end of their returns on any new investment.

- CRT countries that operate at CRT appear to have some rather minimal congestion problems; otherwise, they are highly efficient in their allocation of resources.
- IRS countries, arguably at the other side of the investment scale, have a much lower EFF index, due almost equally to Scale and Congestion problems, and they still exhibit some technical inefficiencies, not due to either congestion or scale.

Characteristically almost all countries that are classified as “leaders” of innovation operate under decreasing returns to scale (DRS), which can indicate, that improvements are becoming more and more difficult. “Catching-up” countries operate predominantly under constant return to scale, which may indicate, that no strong attempts for improvement is made there. These observations call for further study, though; it should not come as a surprise that leaders in terms of input-to / output-from innovation are frequently technically not effective. For small countries there may be a permanent problem with achieving optimal Return to Scale because of lack of economies of scale and associated synergies. In other cases, problems with congestion may result from a lack of clearly identified patterns of specialization, poor coordination between government supported research institutions and business, inefficient commercialization of inventions, and inadequate transfer of knowledge between various agents involved in pro-innovative activities. Such conclusions call for a more detailed examination, and in particular, detailed assessment of mechanisms embedded in NIS of countries.

Efficiency of turning inputs into outputs is as important as the level of inputs. The use of a non-parametric DEA model provides a methodological extension to the methods for investigation of innovation systems. Farell Input Saving Measure of Technical Efficiency (EFF) can be used to investigate aspects of efficiency of pro-innovation efforts. The results of application of such a methodology may have both practical and scholarly merits. Practical outcomes will directly indicate reasons for inefficiencies, provide suggestions regarding crafting pro-innovative policies, guide operational activities, and simplify assessment of efficiency of activities based on quantitative evidence. Efficient countries and their policies will be identified, thus outlining Best Management Practices (BMP) in the area of stimulation and support of innovativeness. Such results may supplement currently exercised concepts. Scholarly benefits of the study results deal with the contribution to an ongoing debate about the means in which to stimulate innovation, to determine the ranking of countries, and to establish the theoretical underpinnings of being an innovation leader. This methodology may bring novel perspectives to the investigation of the problems of innovativeness.

6 Instead of summary

In the myriad of reports on interpretations of innovativeness it is somewhat counterproductive to argue which interpretation is more correct or appropriate. While continuing to studying the topic, a clear interpretation should be accepted and consistently used. Under the circumstances it is acknowledged that innovativeness is a multidimensional, complex phenomenon; not defined precisely; not prone for operationalization, and its interpretation may be impacted by several situational elements and interdependencies between subdimensions. Certainly, it would be very convenient to get access to a comprehensive composite index of innovativeness that is simple and clear; based on easily available and reliable data; an index that remains unchanged in terms of indicators selected over prolonged period of time; that captures issues of inventiveness and innovativeness; pertinent for big as well as for small enterprises; that may contain policy-setting suggestions.

The assessment of technical efficiency of innovation efforts is probably the most desirable outcome of further studies. Based on the assessment of efficiency the key points for policies oriented on enhancing innovativeness can be established. These key points, along with the results of analysis of detailed innovation policies, may lead to the identification of “Best Management Practices in Innovations” (BMPI), that applicable to the specific context. If some stability while measuring innovativeness is achieved, longitudinal studies may be undertaken cross-validating assessment of accuracy of procedures and policies. Results will bring more clarity to the quandary: are countries and companies innovative because they are rich, or is it vice-versa, and countries and companies become rich when they become innovative. Certainly the problem of isolation of results of assessments from market forces and contextual elements should be explained. When results of such studies become available a more precise taxonomy of countries can be developed. As it stands now, "the more you spend the better is country's ranking": such a classification can be enhanced with comments regarding efficiency in terms of utilization of available resources. Again, conclusion from such a study may assist in identification of the extent to which the alleged decrease in the productivity growth of many countries can be explained by differences in efficiency and by differences in its components, namely scale and congestion. Some results, along this line of reasoning have been already published (Nasierowski & Arcelus [49]). These results indicated, that globalization of business practices lead to the harmonization of policies dealing with the acquisition and development of technology throughout the years and across countries. Additionally, a classification of countries into two clusters based on their commitment to technology development has been presented. Indexes of commitment to technological change were identified and countries were ranked according to their technological competitiveness. These results may also be influential in terms of operationalization of National Innovation Systems and the clarification of the dichotomy between macro-economic perceptions of innovativeness and micro-economic reality.

There are still several important to economic progress topics in the field of innovativeness which exploration is warranted. Some prepositions to be investigated:

H1: Rich countries are not technically efficient in the area of innovativeness because of congestion.

H2: Small countries are not technically efficient in the area of innovativeness because of insufficient economies of scale and deficiencies in synergies in undertaken projects.

H3: Problems of congestion and scale are exacerbated when there are structural problems with formulation of NIS (e.g., inadequate specialization patterns, insufficient coordination mechanisms, deficiencies in management of NIS, etc.).

H4: Rich countries frequently overinvest. Frequently, countries classified as non-innovative, indeed invest less in innovations, but do it efficiently.

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A NEW CONCEPT OF EVALUATION OF THE PRODUCTION ASSETS

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Abstract: Production assets management in a company is a traditional function, which in the period of transition of the Polish economy gradually lost the role of co-relation with the production function to the function of marketing and sales, finance or even logistics. An efficiency was selected as the main operating criterion at the company level i.e. the ability to reach a set goal of the final activities. Technological efficiency at the level of the production station is expressed by the ratio of technological efficiency, at the level of production cell the efficiency of technology influence on efficiency of production cell. The inspiration for this paper were the new approach to company value on the market, including the value of assets, and advancement in the production technology and an appearance of modern tools.

Keywords: production assets and technological efficiency in the enterprise, flexible and innovative production, quality and price efficiency, market demands, value and company management.

1 Introduction

Business processes in companies are strictly related to the asset management. In the period of structural changes the following factors affect the effectiveness of production assets: asset restructuring, privatization, implementation of quality assurance systems, new markets and new technology, also internationalization and globalization in the multinational business. Competitors on the markets of all industries focused their activities and aimed at utilizing economies of scale of production and the new role of marketing. Maintaining the conventional production equipment it is impossible to meet new requirements and compete on the market in the future. The preferred variant of technology selected on the basis work consumption minimization criterion led to a large fall in employment, however, the development investment guarantees significant growth in efficiency of companies. The market is characterized by high influence of innovation in products on technology modernization.

Gradual implementation of new technologies and modern production processes into businesses requires increased efficiency of production assets. Innovation in technology became the main driving force behind the decrease in costs, increased productivity and increased quality. The fixed assets analysis traditionally comprises a set of partial ratios such as: fixed assets possession ratio, modernity of fixed assets ratio, and fixed assets utilization ratio. The productivity ratio is a synthetic measurement tool. The matters of technical system exploitation efficiency is further developed in the science of exploitation. A new idea of efficiency results from a research assumption that development of production systems, including technology and production, shaped by the market needs, is the basis for production assets efficiency.

2 The genesis of the problem of assets and efficiency in the enterprise

2.1 Market impact on the development of production in the enterprise

Production assets management in a company is a traditional function, which in the period of transition of the Polish economy gradually lost the role of co-relation with the production function to the function of marketing and sales, finance, or even logistics. A new approach to company value on the market, including the value of assets, and advancement in the production technology and appearance of modern tools are an inspiration for search of such production fixed assets which would constitute a material source of competition in the scope of quality, efficiency and utilization and costs.

The management cadre tend to forget that in modern companies the highest element of costs is not an employee, but the depreciation of a machine. Advancements in technology are so fast nowadays that it is difficult to assume a 20 year machine exploitation time (recommended time – 5 years).

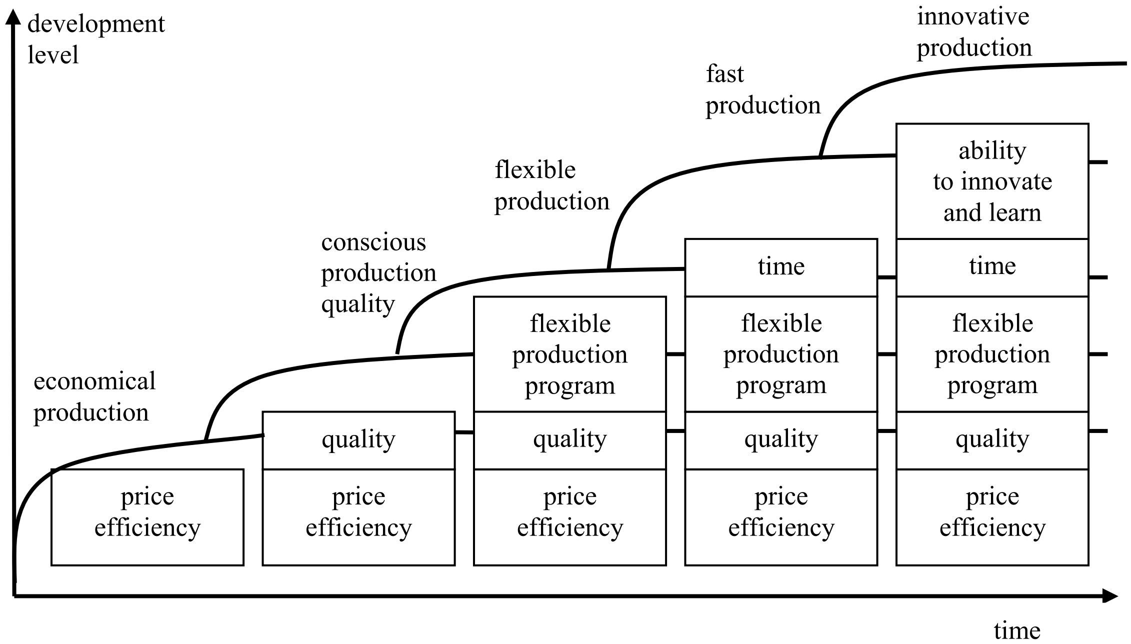

Figure 1. Evolution of production as a consequence of changing market demands (*source: G. Spur [52]*)

A higher efficiency of machines results enforced higher efficiency of an employee.

Apart from quality, productivity and cost reduction producers should present flexibility of operations i.e. an ability to provide a fast and efficient reaction to the needs of the market and client's preferences. One of the main goals of a company is to define a product and ensure its place on the market. Execution of the goal requires new product planning, flexible manufacturing and introduction of the products on the market.

The fundament of balanced growth strategy of companies is efficient basic functioning of the production system. The business is shaped by market needs supported by the rules of the market economy on one hand (from outside to inside) and from the other side (from inside to outside) by production potential limited by technology and means of work. In order to increase client satisfaction and efficiency of production the space between the demand and the supply and the client and the producer is filled with advancement in manufacturing technology and processes of integration of human and technical resources. J. Honczarenko [15, p. 27] explains that the manufacturing process is subject to change starting from mass production to the philosophy of flexible, cost-effective, lean to agile manufacturing.

The evolution of production (Fig. 1) develops from economical production to innovation in the production. The essence of Fig. 1 is the presented need for purchase of new skills by organizations, in order to meet increasing and more complex market needs.

Production is a function in a company, therefore like any other function it is a means to goal of an organization as a whole. Goals require engaging the management cadre – including the production department cadre. The goals of a company are generally of economic, material, system nature and are the main criteria of selection of type and direction of activities. For example: execution of a sales plan, increase in profits, development of new products, implementation of a new technology.

Strategic decisions taken within the production function are developed into tactical and operating decisions (what technologies are appropriate for the assumed scale of production, reliability of equipment, ensuring quality, logistics, and production financing).

One of operating decisions is a plan of readiness and reliability maintenance of the production assets. Execution of plans often requires investment – purchase of new means of work, liquidation of worn ones. A company's ability to compete on a free market requires an intensification of the production business through utilization of all sources of increasing efficiency of its work. A substantial source is effective production assets management.

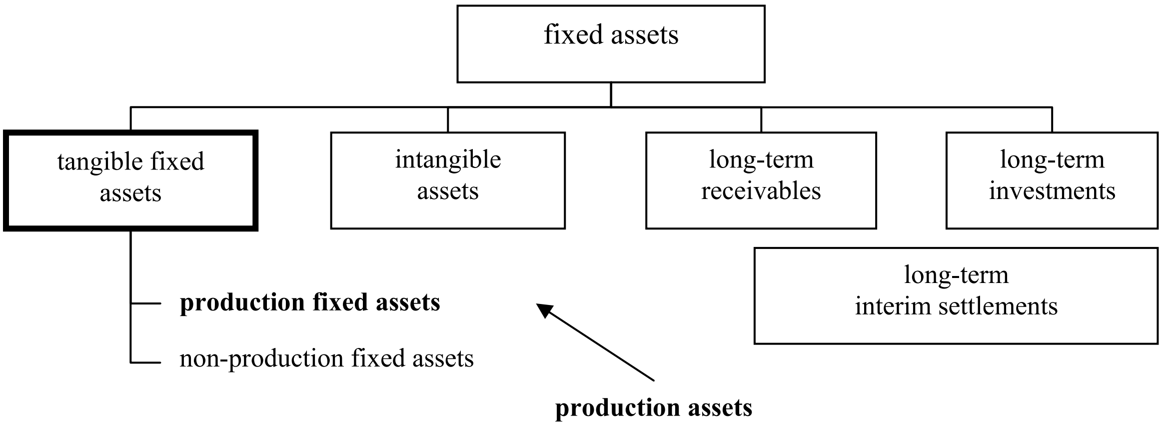

Figure 2. Division of fixed assets with indication of production assets
(*source: author's own work on the basis of the accounting law [54]*)

Introduction of new technologies and methods of production results in dilution of quantitative criteria of production scale division, sizes of production batches and the number of various products in the production system. Also production assets efficiency limited to an economic criterion is often in the statistical dimension in the production business. Traditional production systems with excessive production capabilities, show a tendency to decrease the machine utilization time ratio. Experience from exploitation of advanced production systems shows that as a result of dynamic allocation of tasks the load on particular machines increases, however, it is not a factor that decides about the economic efficiency of the system. The decisive factor becomes the disposable time of the system, not exploitation costs.

Innovative production cannot be based on advanced technology alone, but also requires a production structure creation, which will be able to adopt to changing conditions and manufacture a wide range of products using the same available means.

2.2 Definitions, functions and efficiency of production assets

Production assets are key asset resources, which are divided [54, p. 67] into: intangible assets, material fixed assets, long-term receivables, long-term investment and long-term interim settlements (see Fig. 2).

Fixed assets [54, art. 3, section 1, point 12-13] are defined as assets not classified into trading ones, being „controlled by the entity resources of credible value, being a result of past occurrences, which will result in future inflow of economic benefit into the company". Controlling of assets means that the given entity is able to receive future economic benefit resulting from the use of available items of assets.

Fixed assets are working mean aimed at production goals [4, p. 12] in a longer period of time, maintaining their natural physical form, not being a part of products manufactured by their use. Fixed assets are work means of set value and time of use.

In the science of machine and technical means exploitation there are following definitions: single technical object, a group of technical objects, exploitation object, exploitation system, technical system, exploitation of technical systems.

In the engineering of production ([10], [11], and [15]) a system, a technical system, manufacturing, production, manufacturing system, production system, technical means of production. I. Durlik [11, p. 33-34] divides technical production means, as one of basic elements of the input vectors into production system:

- the premises of manufacturing plant and the production area,
- technological equipment,
- buildings,
- piping, electrical installation, IT network.

Characteristics of fixed assets according to varying criteria of division defines and sets the structure of means collection, their destination and way of use.

On the basis of the function (destination) criterion performed by fixed assets numerous researchers ([4],

[16]), and the industrial practice defines two basic groups:

- production fixed assets,
- non-production fixed assets.

The difference between the production and non-production fixed assets is such that in the production process the value production fixed assets is transferred in amortization on manufactured products.

The criterion of production necessity and relevance are characteristics of working means [16, p. 23], and without participation of means of this type, it is impossible to deliver the production process relevant to the given company.

Production assets

Production assets are a part of fixed assets not classified as non-production fixed assets, meeting the criterion of production necessity and relevance and used for realization goals of the company and the functioning of production systems.

In the multidirectional effect of fixed assets on the quality of the production process there are following functions to be distinguished: technical, technological, economic, social, and asset ones.

Technical function

Technical function is delivered through relations of material objects, structures describing the location of elements in relation to one another, and reason-effect mechanisms resulting in processing energy and information. A change in the level of physical values is described as the physical and chemical state, which the basis for a formal description of technical state of facilities.

Reliability and durability are considered main criteria of assessment of useful value of the currently produced manufacturing equipment. The period of exploitation may be considered a measure of durability. An efficiency of facilities comprising the fixed assets, decreases over time of exploitation. Reliability is defined as a quality of a facility set as its capability (the level of trust) for proper functioning within a set time and set circumstances.

The development of technical function not only in the product or engineering innovation, but also the market one, positively affects the increase in production machinery and equipment efficiency.

Technological function

Technological function – shapes the manufacturing processes and the type of applied technology, affects the continuity and type of processes over time. Technological facilities fulfill not only basic functions, but also auxiliary ones.

Technological function is normally interpreted as a function related to the manufacturing process. The function is directly related to the accuracy and efficiency of a process and technological complexity of the structure. A decrease in the work consumption is possible in a technological process. Automation is a concept of technological system [9, p. 34]. New technologies and flexible manufacturing processes ensure substantial improvement in reliability and stability of production process. An evaluation of the technological position of a company enables determination of a „technology gap" – which limits development of a company. Currently technology is a new factor of company competitiveness.

Economic function

Purchase of items of fixed assets requires investment expenditure and then expenses in the form of labor costs, and facility maintenance in the manufacturing process. Depreciation of fixed assets is an economic category, that may serve the purpose restoration of facilities, in order to counter the process of their further wear. Depreciation serves a function of transferring the worn fixed assets value onto the production costs. The criteria of technology attractiveness and competitiveness, as well as fixed assets, are considered economic criteria. The economic function – often as an obligatory requirement, affects undertaking activities aimed at improvement of production capabilities utilization. Production costs depend on the size and variety of manufacturing. The choice of reconstruction form is affected not only by technical factors, but also the economical ones.

Development of new technologies increase capital requirement. A company functions in a set economic system, and the economic function is an integrator of its internal and external functions.

Social function

Manufacturing business creates work places. Capital consumption of workstations affects the amount and type of work. Development of key technology eases human effort at work and increases employment of skilled staff with new qualifications.

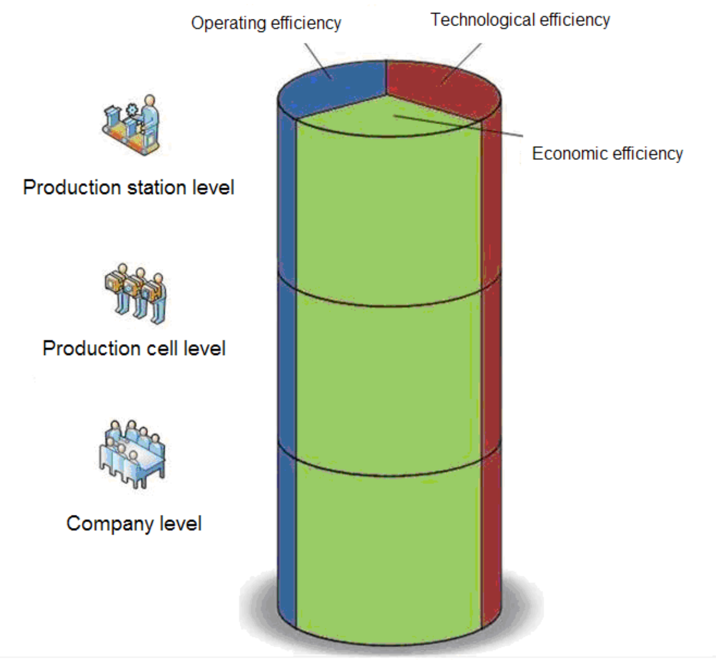

Figure 3. Areas of assessment of production assets efficiency
(*source: author's own work)*

Technological advancement deepens the process of societies qualifications all over the world. Together with the development increases productivity measured as value of sales pre one employee.

Employees require of a company that their work makes sense and was something serious [9, p. 289], and the way of their work organization indicated an employer's interest in good work. A new accent of a social function is the social and cultural aspect of human resources in the organization of work.

Moreover, the social function covers the tasks of improved working conditions and should indicate information about negative results of work in a given place of work.

Restructuring activities [17, p. 110] in the Polish economy affected: changes in the employment structure, improved discipline of work, promotion of employees' creativity, limitation of the social function.

Asset function

Asset function – in the process of company value management there emerges a role for the assets function and its influence on productivity. A subject of analysis may be a company as a whole, or its separated part, or items of assets. An instrument of asset function are methods of valuation of assets and company revenue [40, p. 26-32],

Key elements of the valuation, that affect the assessment of the company, are:

- market value of shares,
- net assets value,
- growth in profit per share ratio,
- operating and financial risk.

A new role of assets in the economy affected the shaping of a new ownership structure.

The asset function is information about the real economic value of a given entity and argumentation upon decisions regarding purchase or sale of items of fixed assets. The listed functions of production assets in business activities indicated areas in which possibility of increased efficiency of the assets may be found.

Production assets efficiency

The notion of production assets efficiency is not unambiguous, which results from the very nature of efficiency, the method of its expressing and measuring (see Fig. 3).

M. Bielski [2, p. 104] explains that companies, in the decision-making process, are guided by adopted goals and possibly low expenditure on their achievement, should asses efficiency as the level of achievement of set goals, and then the level of utilization of possessed resources.

It may be stressed that the unambiguous notion of efficiency does not limit us to only determining general company efficiency – as a synthetic measurement, but also leaves room for the choice of selection of ratios and efficiency measures in implementation of ventures relating to particular functions or resources (including production assets).

Therefore, numerous particular efficiency notions, such as: economic efficiency – the result of business activities calculated as reached result to the input, organizational efficiency, adaptive efficiency], and innovative efficiency.

Operating efficiency [49, p. 63] related onto fixed assets is a quality determining their ability of being the efficiency mode, enabling delivery of set production tasks. The qualities of fixed assets, in such a form of defining operating efficiency, are: reliability, readiness, and lifetime.
There are substantial efficiency increase possibilities on the border between technology and production, the use and maintenance of machinery, and product design and technology.

Fixed assets efficiency is a multidimensional notion, therefore, the economic, technical, organizational and management literature comprises term such as: efficiency, efficacy, usefulness, reliability, productivity, economy. A synthetic fixed assets efficiency measure [16, p. 193], sets an economic variable, expressing a relation of a given goal function level of a company F to expenditure (resources) of fixed assets N, necessary for execution of the function:

$$E_m = \frac{F}{N} \tag{1}$$

Such formulated fixed assets efficiency measure is a mirror of production means efficiency measure expressed by the goal realization level and the size of effort borne in relation to the effort or resources of the factors.

Another form of the above presented E_m formula is as follows [16, p. 193]:

$$E_m = \frac{Z}{K_m} \tag{2}$$

where:
Z – the level of financial result (profit) of the company,
K_m – costs of exploitation of fixed assets.

The presented relation between the exploitation costs may lead to a stimulation of fixed assets efficiency increase in a company.

R. Borowiecki [4, p. 93] suggest two phase study of fixed assets management efficiency. The first phase assumes assessment of fixed assets productivity in relation to work efficiency and its technical equipment as a starting point for assessment of the company management in the scope of fixed assets utilization.

The second phase – there are detailed studies covering the following: ratios and coefficients of the size of fixed assets; the ratios of technical advancement in the area of fixed assets; ratios and coefficients of utilization of machines and equipment space.

2.3 The goals and scope of production assets efficiency

The main goal, which is increased assets efficiency, was set a company level – a business entity running production or service business on its own, in order to gain benefits. A production entity, as an open system comprises numerous sub-systems: development, manufacturing, supply, maintenance, information, and management. Material production factors of a system comprise material grounds for growth in utilization of production capabilities of an entity.

Partial goals are reached in a given period of time and space using certain resources. A program of assets efficiency improvement may comprise numerous partial goals such as: optimal deployment of workstations, improvement in raw material flow in the manufacturing process, shortening in technological times as a result of introduction of a new technology, increase in productivity of manufacturing workstations.

Goals related to usage of production assets may stress the varying needs of processes and their importance in a company. For example: the main goal of production assets, in respect to the process continuity criterion, is to maintain efficient manufacturing guaranteeing productivity, quality and safety.

An energy efficiency improvement program in a company comprises goals of decreased energy costs of production halls and energy-saving equipment. An increase in production assets efficiency may be executed through:

- new and modern technological solutions,
- increased efficiency of workstations,
- utilization of production capability,
- efficient acquisition of orders,
- staff training on the exploitation of manufacturing equipment.

Production assets efficiency may be discussed from various point of view, therefore there might be varying assessment criteria, such as:

- economy, setting a relation between the value of gained effects and a the level of efforts borne in a given period of time during the use of the assets,
- efficiency, an ability to reach states with positive evaluation from the achievement of external goal point of view.
- efficacy, a quality of assets enabling a possibility of remaining in the state of ability of full execution of production goals,
- readiness, a quality of assets expressing a capabilities necessary in a given period of time for delivery of the use process in line with technological requirements,
- effectiveness, setting out the intensity of execution of production tasks,
- capital consumption of manufacturing workstations, which increases with technology development.

The scope of production assets efficiency is limited by two elements: the first one – the level of efficiency, the second one – the criteria of efficiency. In a reference standard there are three levels of increased efficiency:

1) the enterprise level (a production system),
2) the production cell level,
3) the manufacturing workstation level,

and three criteria of assessment (evaluation) of efficiency:

1) economic criterion,
2) technological criterion,
3) operating criterion.

As a result of such division there are nine areas of increase and assessment of production assets efficiency in a company. Each level is subject to evaluation of the following types of efficiency: economic, technological, and operating one.

3 Conditions for change and their impact on the management of productive assets

3.1 Analysis and assessment of fixed assets efficiency

The business of each company, including its fixed assets and processes, requires periodical analysis and assessment. An analysis should allow, on one hand, determination whether the to date destination and utilization of production assets brings expected results (an ex post analysis), and, on the other hand, enable determination of directions and methods of increasing efficiency in the manufacturing process (an ex ante analysis). An analysis applying to the company assets management is generally know as assets analysis.

An ex post analysis of fixed assets efficiency was a subject of intense studies and literature until the 1990s. Economic changes introducing free market require a new approach to searching for direction and methods of increasing production assets efficiency.

From the subject point of view the following analysis and evaluation techniques are worth mentioning:

- productivity – a synthetic measure of fixed assets efficiency,
- utilization of fixed assets,
- influence of fixed assets on production and financial results.

A universal formula – fixed assets management is based on the rational management principle. The core of the principle is ensuring such management so that with „a given level of effort receive highest possible level of goal achievement, or upon a give goal achievement level utilize the lowest possible level of effort" [1, p. 13]. The first part O. Lange [14, pp. 217-218] is known as the highest effect principle, or highest efficiency principle, the second one – the lowest effort principle, or the cost-efficiency principle.

A consequence of the principle is a scope of fixed assets efficiency in question, covering activities aimed at intensification of fixed assets management strategy (restructuring, utilization, restoration, modernization, development) ([43, p. 11], [20] and [57]).

„Fixed assets management is the whole of planned, organizationally ordered and continual activities aimed at securing its resources, their readiness for production, and appropriate application in the manufacturing process, and reproduction that is adequate to the development tasks of the company, in line with its production needs" [43, p. 13].

The relation between the scope pursuit goal and the sum of efforts is a measure of management efficiency. In an analysis of fixed assets, the following general ratios are derived from two basic economic values of a company: production (P), employment (Z), fixed assets (M):

- fixed assets productivity ratio (P : M),
- technical equipment of work ratio (M : Z),

- efficiency ratio (P : Z),
- production work consumption ratio (M : P)

$$\frac{P}{M} = \frac{P}{Z} : \frac{M}{Z} \qquad (3)$$

R. Borowiecki [4, pp. 52-56] presents cases of co-relation from the formula (3) and influence of production, employment, and fixed assets on changes in productivity.

The following set of partial ratios is also used in fixed assets analysis:

a) ratios of fixed assets ownership (value, structure, wear level, depreciation);
b) ratios of fixed assets modernity (e.g. numerical control, automated measurements, etc.);
c) ratios of fixed assets utilization (time, efficiency, area occupied, modernity).

Changes in partial ratios, due to the requirements of statistical analysis, and economic studies in the aspect of planned business, had varying accents in their content and evaluation. A result of the change is a decrease in the level of interest of the middle management level in the practice of decision taking, in particular regarding production. Numerous of those ratios were transferred to the production continuity functions.

After 1990 a new meaning emerged for the financial analysis, comprising vertical analysis of assets, including fixed assets and current assets.

An assessment of fixed assets efficiency may be made on the basis a comparative analysis based on specimen set of inequalities of ratios [2, p. 40].

A specimen set of inequalities of basic quantity ratios is as follows:

$$I_R < I_M < I_P < I_Z \qquad (4)$$

where:

I – dynamics index,
R – employment level,
M – state of items of assets,
P – sales revenues,
Z – profit of the company.

Technological progress of fixed assets should have higher dynamics in relation to employment. The process contributes to an increase in efficiency, resulting in higher production dynamics. The profit dynamics grow faster than the production dynamics. A specimen set of inequalities is difficult to establish in the conditions of variable external environment of companies.

In methods of analysis of economic efficiency of fixed assets in a company the following methods are presented [16, pp. 204-220]:

- econometrical methods of fixed assets efficiency assessment,
- benchmarking analysis of fixed assets efficiency analysis.

The topic of technical systems exploitation efficiency is developed in studies of exploitation science development [74, pp. 95-121]. Z. Cygan stresses the cognitive meaning of technical and economical ratios of exploitation [5].

The purpose of analysis and assessment of production assets efficiency is achievement of effective management of assets and assessment of the influence of assets on economic and financial results of an enterprise.

3.2 Production assets as elements of value of a company

A condition for efficient company management is the motion of value creation not only in the long-term cash flow, but also in the profit per share area. The growth in value depends on goals set at the strategic level, regarding the area of business. From this point of view investment decisions become important. Fixed assets are of investment nature. In the value management process there is a problem of assets valuation and their influence on productivity.

The size of assets may be discusses only when there exist conditions of their useful value. The value of assets determines the value of financial assets which would have to be allocated at restoration of assets in a given time, necessary for further functioning of the company. The following are qualities of value of assets [22, p. 47]:

- the value of assets is a current value as at the time of assessment,
- the value of assets is a value of continuation of business running and not the value of its liquidation,
- the value of assets is a total of amounts set for the restoration of particular items of assets.

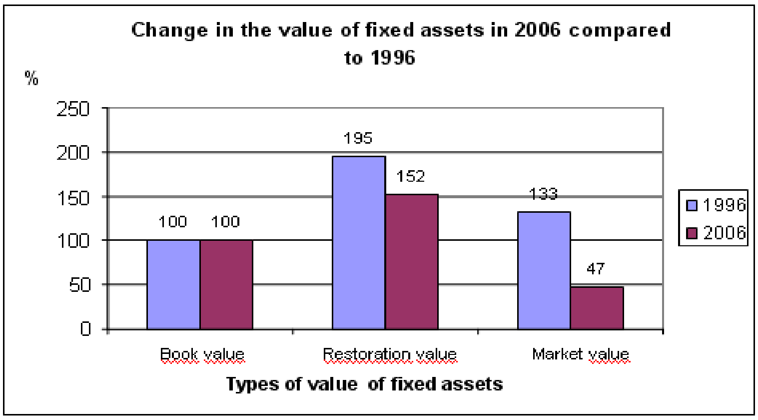

Figure 4. Changes in the value of fixed assets
(*source: author's own work*)

A relation between the assets and revenue value of a company has various forms of relation expresses in the formulas [22, pp. 63, 65 and 67]:

$$W = W^M + a\left(\frac{Z}{r} - W^M\right) \quad (5)$$

$$W = \frac{1}{2}(W^M + W^D)$$

or (6)

$$W = \frac{1}{3}(W^M + 2W^D)$$

where:

W – company value;
W^M – assets value,
Z – standardized annual profit,
r – capitalization rate,
a – weigh factor,
W^D – revenue value.

The following assets methods serve the purpose of assets valuation:

- balance sheet method of net assets valuation, or adjusted net assets method.
- restoration method,
- liquidation method.

Fig. 4 presents a change in the value of fixed assets.

Calculation of a company value using the method of adjusted book value of net assets is performed according to a general formula [36, p. 228],:

$$W_P = (A + K_A) - (P_O + K_{P_O}) \quad (7)$$

where:

W_P – company value,
A – balance sheet value of assets,
K_A – adjustment of balance sheet value of assets,
P_0 – external liabilities,
K_{P_O} – adjustment of balance sheet value of external liabilities.

The company value using the restoration method is calculated using the following formula:

$$W_P = (A + \Delta N) * (1 - Z_F) \quad (8)$$

where:

W_P – company value,
Δ N – difference in expenditure borne on new material potential,
Z_F – physical wear of items of material assets.

The value of production assets totally or partially (together with the revenue value) directly affects the company value. In assessment of company value in the revenue method a discounted cash flow method is used. According to experts it is the basic method used in analyses of trade in companies. Increased production assets efficiency increases the revenue value of a company.

3.3 Studies over fixed assets efficiency management in the company management

There are three periods in the evolution of fixed assets efficiency management in Polish companies:

a) Fixed assets management efficiency (years 1970 – 1989)

A monographic elaboration on the topic is a publication of R. Borowiecki [4], where the following issues were presented: the role of fixed assets in the manufacturing business of an enterprise, a relation between fixed assets productivity and basic economic relations, the rules of selection and application of measures for assessment of fixed assets management efficiency. The author explains and applies productivity as a synthetic measure of fixed assets management efficiency in a company.

In a publication of W. Janasz, E. Urbańczyk and T. Waśniewski [16], were presented three areas of studies in fixed assets management: wear and tear and economic calculus of fixed assets restoration, the influence of the economic and financial system on the restoration of fixed assets, methods of analysis of economic efficiency of fixed assets and an analysis of efficiency of utilization of fixed assets and its influence on production and financial results.

A work edited by J. Rokita [39], is dedicated to methods of fixed assets management assessment in a company. The scope of the method is of universal nature.

The movement toward productivity in the world is an impulse for research and a new look at the idea of productivity, ratios of productivity, factors affecting an increase in productivity, and productivity improvement programs ([37], [41]). It is a complex approach to productivity assessment in a company.

A development of the science of exploitation contains the issue of efficiency of technical systems exploitation, including works of Z. Cygan [5, pp.119-134], J. Lewandowski [24]. Exploitation is an interdisciplinary science consisting of tribology, elements of reliability and restoration theory, the study of reliability, technical diagnostics and efficiency of exploitation of technical systems. The studies on exploitation indicated that unjustified intensity of utilization of fixed assets without rational maintenance services – in the 1970s led to deterioration of production assets. The useful potential is a measure of a machine capability for use, however the servicing potential is a measure of machine's needs for service.

b) Restructuring of fixed assets (years 1990 – 2000)

Main problems of efficiency of company management in the years 1990 – 2000 were focused on restructuring. Restructuring of fixed assets is considered an area of qualitative changes (a change in technology and work organizations) and is aimed at increased efficiency of production capital of an enterprise. P. Glikman [12, pp. 33-44] stresses that an increase in efficiency, studied in variants: non-investment and investment, requires rejuvenation of fixed assets and am estimation of changes in employment in an economy. Z. Czyżewska [6, pp. 55-72], stresses that the structural aspects of labor resources and fixed assets management are a trial of capabilities of deciding a problem of reproduction scale of assets and the type of investment, and a speed of changes in introducing new manufacturing techniques.

Restructuring the scope of business of companies, means returning to the core competence, i.e. an area of specialization of the company [48, p. 45]. The first task in the restructuring process was getting rid of unused, obsolete fixed assets. Changes in technology were a stimulus for action in the scope of machines and manufacturing equipment replacement. An effect of these activities is a new configuration of business areas with long-term business strategy.

Ownership transformation and privatization required credible methods of valuation. Restructuring of fixed assets contributed to an increase in production assets efficiency.

c) Fixed assets management (from 2000 to now)

A rebuilding of Polish companies and adjustment to the changing environment and growing quality, efficiency, and timing requirements, requires an improvement in the material assets management, and in particular production fixed assets. The management of fixed assets comprises an integral part of company management.

New technologies are new means of work and their application brings desired technical and economical, but also social results. Attractiveness of technology contributes to a decrease in production costs and an increase in quality. It is a factor of increased sales of product on internal and external markets, and at the same time affect better utilization of production assets. New technologies are the starting point for effective creation of a manufacturing system without constant human intervention.

Radical and evolutionary changes in years 1990-1999 led to Polish companies introducing into practice new concepts of management sourced in the Lean Management process [3]. The pursuit of increased efficiency and shorter times of processes requires a complex Total Productive Manufacturing, a complex Total Productive Maintenance ([27], [8], [25] and [51]), Facility Management [53].

A new measure of production assets efficiency is OEE (Overall Equipment Effectiveness). Availability of complex workstations and production cells affects better utilization of production process capability.

4 New concept of evaluation of assets the production business of enterprise

4.1 The goals of assets efficiency study in the production business

Development of production systems results from market requirements, but also from manufacturing technologies, methods and techniques of production management available for application in a company.

Technology is often listed as a factor of international competition of companies. A common element for companies achieving large and small successes is a fact that they achieve efficiency (widely defined) through implementation of innovation. Innovation should be perceived more as cumulated improvements and ideas rather than a significant technological breakthrough [46, p. 154]. Innovation mechanism known to one part of a company may be used in another part, which requires improvement (reformation). For example; management – production – maintenance of machine running.

New concept of efficiency results from adoption of a research assumption that development of production systems, including technology and production, shaped by market needs, is a condition of production assets efficiency.

One of the factors of production development is durability and restoration of work means. Restoration of means of work means adjustment of potential production capabilities to changing environment. An average period of technical facilities exploitation is much shorter than their potential physical lifetime. First symptoms of loss in assets efficiency may be as follows: high costs, a fall in sales activities, a wide scope of business, obsolete technologies and fixed assets, low efficiency of organization at the level of company. Activities undertaken to improve efficiency are: a change in the investment policy, disposal of unused assets, search of new sales market, new definition of core business, acquisition of new technologies and machines.

The main goal of a new study concept is to increase production assets efficiency in a company. Partial goals – enrichment and improvement of assets:

- selection and accessibility of means for achievement of goals,
- efficiency in realization of production tasks,
- an increase in efficiency of workstations,
- an increase in fixed assets productivity,
- a decrease in own costs of production.

Increased assets efficiency is characterized by a system analysis qualities, and its frequency and scope is determined by projects, ventures, activities contained within company management programs. A system analysis of a problem contains following stages:

- examination of considered goals, or multidirectional ventures,
- an analysis of possible methods of achievement of the goals, considering designs of new solutions,
- assessment of positive and negative results of each variant of conduct with a risk map,
- comparison of variants according to various criteria and assessment enabling selection.

Due to an ambiguous meaning of efficiency, the method of its expression and measurement – in the new concept of increasing assets efficiency there are defined basic business areas affecting the production assets efficiency. Each element of assets efficiency is characterized by measurable qualities and the value of qualities changes over time. The area of efficiency is determined by the reference level of efficiency and the needs for efficiency assessment according to various criteria.

4.2 Areas of increasing production assets efficiency

The state of efficiency is reflected onto defined areas of efficiency:

$$\Omega = \{E_0, E_1, \dots E_k\} \tag{9}$$

where: k = 1, 2, 3,... – the number of defined areas of efficiency.

Among defined areas of efficiency there areas: proposed (target), existing (effective), critical (unwanted):

$$\Omega^{\wedge} \cup \Omega^{o} \cup \Omega^{k} = \Omega \; \Omega^{\wedge} \cap \Omega^{o} \cap \Omega^{k} = \varnothing \tag{10}$$

An increase in production assets efficiency may be executed by changes reflected onto a certain designated area(s) in a set time, or countering the appearance of any unwanted state of efficiency from lack of changes.

The source of increased assets efficiency are: production stations, production units, a company as an organized production system.

Efficiency level	Efficiency criteria: Economic (economic efficiency)	Technological (technological efficiency)	Operating (operating efficiency)
Company	P -E_{ek}	P – E_{tech}	P - O_p
Production cell	K - E_{ek}	K – E_{tech}	K - O_p
Production station	S - E_{ek}	S – E_{tech}	S - O_p

Figure 5. Areas of increased production assets efficiency
(source: author's own work)

The following criteria were chosen for efficiency assessment: operating, technological, and economic.

$$E_m = \{E_{op}, E_{tech}, E_{ek}, R_j\} \quad (11)$$

where:
E_m – production assets efficiency,
E_{op} – operating efficiency,
E_{tech}– technical efficiency,
E_{ek} – economic efficiency,
R_j – relations for j = 1, 2, 3.

The areas of increased production assets efficiency are presented in Fig. 5.

Delivery of the main goal, due to the scale of problem, assumes determination of three levels of efficiency: 10 – company, 20 - production units, 30 – production station and three various criteria of assessment: operating, technological, and economic.

Each designated level of efficiency is a place for improvement of facilities and processes affecting increased efficiency. Rationality in the scope of methods and means of improvement is closely linked with the main goal.

The basic factors shaping production assets efficiency, upon assuming satisfaction of production needs are:

- production system development strategy,
- technique, i.e. the quantity and quality of technical means,
- technology of the manufacturing system,
- composition and structure of the manufacturing system,
- organization and management of the manufacturing process,
- conditions and interaction of the company with its environment.

Production assets efficiency is defined as a capability of technical facilities, comprising the production system, to fulfill set needs of a company in line with its destination and requirements. Requirements are usually divided into: structural, functional and development.

P. Sienkiewicz [49, p. 54] introduces a definition of efficiency of action systems – as a system feature, which expresses rational capabilities of systems for fulfilling certain needs (achievement of set goals of action, function with destination and requirements). Due to a time perspective the author distinguishes potential efficiency, upon assessment of whose only the needs and potential are considered.

Potential efficiency assessment ratio:

$$Fs(t) = \frac{Ws(t)}{Vs(t)} \quad (12)$$

where:
$Ws(t)$ – needs,
$Vs(t)$ – potential.

Assessment of potential system efficiency is an evaluation of the level of possibility of meeting a certain need, whose satisfaction is the goal of an entity. During an ex post assessment there is a notion of executed efficiency, which is a system feature characterizing the level of system's capability utilization in the process of delivery of certain goals and in set conditions. A division of areas of production assets efficiency is illustrated in Fig. 6.

Increasing efficiency is a process of constant improvement. Acceleration of routine processes often brings good results where it is a result of a project such as installation of more efficient machines and equipment. There are also opposite situations, where acceleration of operations results in delays and stoppages, and at the same time in lack of utilization of modern resources.

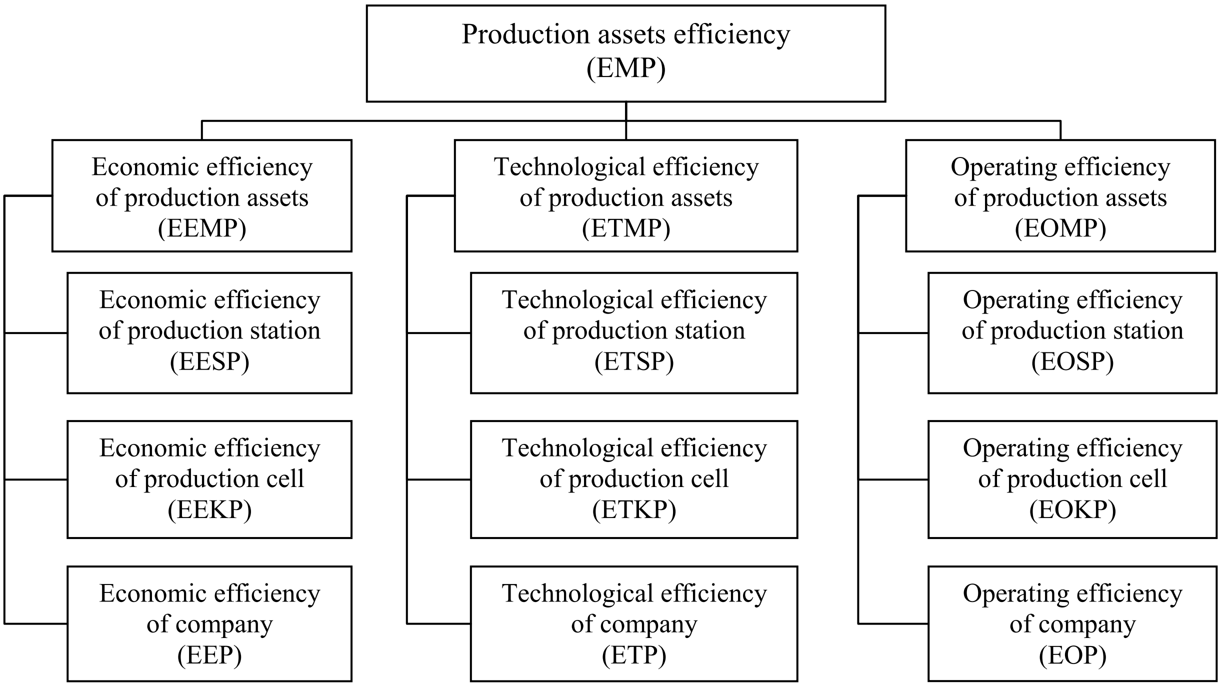

Figure 6. Division of area of production assets efficiency
(source: author's own work)

4.3 Basic methods of assessment of production assets efficiency

4.3.1 Division of assessment methods of production assets efficiency

The number of factors affecting assets efficiency, such as: fluctuations of orders from the market, technological advancement, new methods and techniques of production control, organization and engineering of exploitation and economic factors are the reason for search of new methods of assessment of production assets efficiency. The searched measures of assessment should be an efficient completion of a universal calculation of efficiency assessment.
The universal methods of efficiency assessment comprise:

- investment efficiency calculation,
- methods of efficiency assessment (including productivity),
- a group of ratios form financial statements.

A new concept assumes separation of three groups of assessment of assets efficiency:

- operating efficiency,
- technological efficiency,
- economic efficiency.

4.3.2 Operating efficiency of a production station (technical facility)

Operating efficiency of a production station is a feature expressing the ability of a technical facility to be in the state of efficiency of its elements and structures enabling delivery of set production tasks. The features of operating efficiency comprise: reliability, availability, lifetime. The scope of operating efficiency of a production station takes a form:

$$E_{op} = (N_z \cup W_d \cup W_k) \qquad (13)$$

where:
N_z – reliability,
W_d – efficiency,
W_k – utilization.

a) Reliability of a production station

Reliability of any technical object is often described as quality over time (the characteristics of reliability as a feature of a facility – machine, equipment, set).

The following probability serves as the ratio of assessment of reliability [49]:

$$R(t) = Pr \{T \geq t\} = Pr \{\xi[x(t)], =1\}, \quad t \geq 0 \qquad (14)$$

where:

T – is the moment of process X(t) entering into the set of inefficiency states;

ξ – the function of states:

$S^0 = \{ x \in X : \xi(x) = 1 \}$ – the state of inefficiency,

$S^1 = \{ x \in X : \xi(x) = 0 \}$ – the state of efficiency.

Durability – an ability of the facility to conserve its characteristics and parameters in applied exploitation conditions. For reparable objects durability is defined as the total time of facility work until resignation from its repair.

An indicator of durability of expected time of exploitation (e.g. calculated according to depreciation rate, set economic time of exploitation). The exploitation period is presented by function [41, p. 119]:

$$f: P * S * N * U \rightarrow T \tag{15}$$

where:

$P(p_1, p_2, ..., p_n)$ – the set of technical and exploitation parameters of a machine (technical facility),

$S(s_1, s_2, ..., s_n)$ – a set of parameters and size of the exploitation system,

$N(n_1, n_2, ..., n_k)$ – a set of size of expenditure and running costs of a machine,

$U(u_1, u_2, ..., u_n)$ – a set of parameters of technical advancement in construction and manufacturing technology.

In the T set there are following phases of exploitation: a period of liquidation, a period of exploitation resulting from lowest costs of machine operation, a period of exploitation dependent on the time of replacement of the current machine with a modern one. A signal for an analysis of operating efficiency of a facility is the period of exploitation at the time when the book value of a facility is zero.

Operating readiness:

$$Go\,(t,\tau) = G(t) * G(t, \tau) \tag{16}$$

where:

G(t) – initial readiness (ability to work), an ability of facility enabling its use without breaching the quality of executed functions,

G(t, τ) – task readiness, a quality of facility from the point of view of achievement of an allocated to the facility task. It means that the facility being in the state of work at the moment (t) will still be in that state at the time τ, in order to execute the allocated task. Ensuring required operating readiness at possibly lowest costs may be put down in the form:

$$G_o(t,\tau) = G_o^w(t,\tau) \quad \text{at} \quad k_{ot} \rightarrow \min \tag{17}$$

or achievement of maximum operating readiness at set border costs of facility maintenance may be written in the form:

$$k_{ot} = k_{ot}^g \quad \text{at} \quad G_o^w(t,\tau) \rightarrow \max \tag{18}$$

where:

k_{ot} – facility management costs,

k^g_{ot} – border costs of facility management.

The first step in assessment of operating efficiency of a workstation is assessment of reliability of a technical facility in a complex approach, because reliability affect effective time.

b) Efficiency of a production station

Efficiency is an economic and operating measure of efficiency, considering the level of production reflected on the level of resources used for their production. Efficiency may be reflected on numerous levels of efficiency (company, department, workstation). R.W. Griffin [13, p. 621] distinguishes several forms of efficiency: overall efficiency (multi-factor) – overall productivity is defined in a formula:

$$\text{productivity} = \frac{\text{production}}{\text{expenditure}}$$

where:

expenditure – resources such as: labor, capital, materials, and energy used for manufacturing all products and services; and partial efficiency considering one category of resources, often defined of as labor efficiency, calculated from the relation:

$$\text{labor efficiency} = \frac{\text{production}}{\text{bnp}}$$

where:

bnp – direct labor expenditure (e.g. time of work).

Machine efficiency, determines the number of products manufactured by a machine in a given unit of time (usually one hour, or one shift).

Planned efficiency of a machine is achieved maximum production in ideal conditions in a given period of time (e.g. hour, shift, week) [56, p. 279]:

$$\text{planned efficiency} = \text{production per hour} * \text{number of available hours}$$

The planned efficiency is affected by the manufacturing task dependent on the variety and mass production.

Table 1. Division of states of use
(*source: [41, p. 128]*)

Type of process	States of usage			
	S_1	S_2	S_3	S_4
Single state	Usage			
Two state	movement		Stoppage	
Two state*	work		idleness	

Effective efficiency of mass producing machine is maximum production achieved in the effective working time of the machine.

$$\text{effective efficiency} = \text{production per hour} * \text{number of available hours} * \text{operating readiness}$$

Effective efficiency, apart from production task, depends on the preparatory – completion time and technical time (maintenance, repairs, technical breaks). An increase in efficiency is possible, most of all, through employment of machines with high concentration of tasks in the manufacturing technology.

In designing rhythmical production effective efficiency is replaced with a notion of workstation production capability, set as a product of hourly production capability m_g and time T:

$$M_p = m_g * T \quad (19)$$

where:

$m_g = \frac{1}{t_j}$, t_j – time unit of a technological operation,

Hourly production capability increases when we perform a series of technological operations in an automated cycle.

c) Utilization of a production station

Utilization – the use of a workstation for a given production goal with a benefit for a given task. Division of states of use of production station is presented in Table 1.

The following may be differentiated in the set of usage states:

S_1 – state of effective work,
S_2 – state of idle work,
S_3 – state of stoppage work related to preparation of the effective work,
S_4 – idleness state.

$$U = \{S_1, S_2, S_3, S_4\} \quad (20)$$

Measures of assessment of usage state:

- time of station's usage state
  $T_u(t) = T_1(t) + T_2(t) + T_3(t) + T_4(t)$
- time of station's (technical facility's) movement
  $T_r(t) = T_1(t) + T_2(t)$
- time of station's work
  $T_p(t) = T_1(t) + T_2(t) + T_3(t)$
- time of station's stoppage
  $T_{pr}(t) = T_3(t) + T_4(t)$
- time of station's idleness
  $T_b(t) = T_4(t)$

The station's usage coefficient:

$$W_s = \frac{Tp(t)}{Tu(t)} \quad (21)$$

The station's load coefficient:

$$\eta = \frac{Tr(t)}{t} = \frac{Zg}{Mg} \quad (22)$$

where:

Zg – hourly task,
Mg – production capabilities.

The coefficient of workstation usage expressed in a different form [56, p. 279]:

$$W_s' = \frac{\text{real\_production}}{\text{planned\_efficiency}}$$

The station's load coefficient expressed in a different form:

$$\eta = \frac{\text{real\_production}}{\text{real efficiency}}$$

Calculation of efficiency and utilization of workstations is aimed at selection of the efficiency and usage levels for planned production tasks. Excess or shortage means too high investment in equipment, and shortage may lead to loss of potential sale of products or services.

4.3.3 Operating efficiency of a production cell

Operating efficiency related to production cells is a feature, which expresses capability of production cell for rational utilization of resources upon execution production tasks. The following are qualities of production units: efficiency, production capabilities, utilization of production capabilities.

The area of operating efficiency of production cell has a form:

$$E_{OKP} = (W_{KP} \cup Z_{PP} \cup W_{ZP}) \quad (23)$$

where:
W_{KP} – efficiency of production cell,
Z_{PP} – production capabilities,
W_{ZP} – utilization of production capabilities.

A production cell [11, p. 108] is defined as a relevant element of the production structure with separated particular factors of production, able to perform allocated production tasks.

The basic measure of organizational production units is the production capabilities.

The factors determining production capability are:

- the factors of production (means of work, subject of work, workforce),
- the scope of production and its structure,
- production organization and management,
- the disturbance to the balance between the supply and the demand and the market of suppliers and recipients,
- the investment policy.

In business activities of production companies the efficiency production units is interpreted as the efficiency of production capabilities. It results from the fact that means of work have a relatively stable and objective character and are considered basic factors of production capabilities.

a) Efficiency of production stations in a production cell

Efficiency of groups of uniform production stations (technological nest) id the total of efficiency of particular stations:

$$W_{NSP} = \sum_{i=1}^{n} W_i \quad (24)$$

where:
W_{NSP} – efficiency of groups of uniform production stations,
Wi – efficiency i^{th} production station , for i = 1...n.

Assuming that the efficiency of a station is the production capability of the station ($m_{g\,i}$):

$$W_{NSP} = \sum_{i=1}^{n} m_{gi} \quad (25)$$

The efficiency of groups of production stations, whose work and efficiency are interdependent by the flow of parts and components also depends on the structure of relations between stations in terms of reliability. There are three basis structures of relations: row structure, parallel structure, mixed structure.

Efficiency of group of production stations in a row and mixed structure depends on the stations with the lowest (leading) efficiency, the efficiency of a group of machines in parallel structure is decided by the sum of efficiencies of machines comprising its parts. Immobilization of one of the machines in the row structure decreases the efficiency of the group to zero. A stoppage of one of the machines in a parallel structure decreases the efficiency of a group of machines proportionally to their efficiency.

b) Production capabilities

Production capabilities determine the maximum number of products that may be produced within a set period of time. Production capability sets the real possibility of maximum utilization of machines and equipment and the production space, assuming rational utilization of other factors of production and manufacturing methods.

The measure of production capabilities [28, p. 378] is the ability to perform work in a set period of time, measured by work units. It is often expressed in the category of efficiency, i.e. the quantity of product produced in units of time.

The ratio method of calculation production capabilities is brought down to the relation between capability on the efficiency of workstations and the quantity of time set in a given period.

$$Z_p = \sum_{i=1}^{k} W_{gi} * F_{ei} \quad (26)$$

where:
W_{gi} – efficiency of group of production stations i (i = 1,2,...k),
F_{ei} – effective pool of work time of a group of stations i (i = 1...k).

Efficiency of production capabilities is expressed directly by:

- productivity, the level of production derived from the unit of resource,

- the level of utilization, the level of available production capabilities, which is really utilized.

For production nests at the stage of planning, hourly tasks are planned:

$$Z_g = \frac{P_{ri}}{F_e} \quad (27)$$

where:

$P_{r\,i}$ – a program of production of products i,

F_j – a planned pool of time of production stations in a cell j,

Z_g – hourly task of product output i.

Production capabilities of a production nest:

$$Z_p = Z_g * F_e \quad (28)$$

For a production line production capability is determined from the formula:

$$Z_p = \frac{F_e}{\tau} \quad (29)$$

where:

Fe – effective pool of time of workstations in a line,

τ – production tact.

Production capabilities of the area is determined from a formula:

$$Z_{ps} = F_e * S * W_{ps} \quad (30)$$

where:

Z_{ps} – production capabilities of the area,

F_e – effective pool of work time,

S – area of the production cells [m²],

W_{ps} – productivity coefficient 1 m² (pieces/ m²).

Control over the production capability is related to planning of needs in the scope of the quantity and the quality of production workstations.

Apart from a ratio based method of establishment of production capabilities one may use others [32, p. 44], such as: analytical method, normative method, or use methods of linear programming. Substantial extension of production capabilities requires appropriate investment in possible application of efficient means of work and processes, application of automation and shortening of introduction times (mass and flexible production).

c) Utilization of production capabilities

Utilization of production capabilities is an activity aimed at uninterrupted functioning of the production system. In fact, the activity is aimed at maintenance of production capabilities above such a level of utilization which enables functioning of the system at a variable level of production orders. The level of utilization often results from a set profitability level for the production system.

The function of utilization result takes a form:

$$W_{ZP} : W_E \times X_R \rightarrow R \quad (31)$$

where:

W_E – input (a set of production factors),

R – output (a set of products –reaction to production orders),

X_R – a set of regulations of production orders.

The following types of processes might be distinguished in the utilization process:

- determined,
- variable (slowly changing tendencies with seasonal variations),
- utilization dependent on highly variable conditions of business (mainly external).

Observation of the intensity of orders enables adequate planning of changes in the portfolio of orders for a determined and variable processes of utilization of production capabilities.

Utilization in a short time (month, quarter), upon assuming a determined process, is expressed by a relation:

$$W_{ZP} = \mu_W \cdot t_W \quad (32)$$

where:

μ_W – intensity of utilization of production capabilities,

t_W – the time of utilization of capability resulting from the load on workstations of production cell.

In recent years a lot of Polish companies have introduced TPM (Total Productive Maintenance) – a philosophy of increased productivity, based on maximization of the OEE-Overall Equipment Effectiveness).

The OEE ratio describes three areas of machine application in a production process defined in a formula ([27, p. 20], [51, p. 65]):

$$\text{OEE} = \text{availability of machines} * \text{eficiency} * \text{quality}$$

Risk and uncertainty affect the level of reserve production capabilities, which is a difference between planned production and the level of manufactured production in a company:

$$R_{ZP}(t) = [Z_{PP}(t) - P_W(t)],* W_{ZP}(t) \quad (33)$$

where:

$R_{ZP}(t)$ – production reserve in period t ($t = \tau_1, \tau_{2,\ldots} \tau_k$),

$Z_{PP}(t)$ – planned production capabilities in period t ($t = \tau_1, \tau_{2, \dots} \tau_k$),
$P_W(t)$ – the level of manufacture production in period t ($t = \tau_1, \tau_{2 \dots\dots} \tau_k$),
$W_{ZP}(t)$ – the level of effective utilization of production capabilities in period t ($t = \tau_1, \tau_{2, \dots} \tau_k$).

The basic goal of examination of production capabilities reserves [32, p. 52] is a possibility of increased production without increasing production potential. In business activities reserves are divided into two groups:

- intensive reserves, resulting from a need for increased efficiency of machines and equipment,
- extensive reserves relating to a possibility of increasing the time of work of means of work and loan on the production area.

Production capabilities and their utilization is a reflection of quality, precision, and ensuring long-term efficiency with continuation of innovation, utilization of technological position on the market and maintenance of production in highly profitable countries.

4.3.4 Operating efficiency of a company

Efficiency was set as the main operating criterion at the level of company, i.e. the ability to reach the set goal of final activity.

One may assume that effectiveness, or efficiency is defined as the level of compliance between results and goals of activities.

R.W. Griffin [13, pp.127-128], distinguishes following models of organization efficiency:

- system – resource approach (concentration on resources, which an organization may secure for itself in business),
- target approach (selection of targets and their subsequent achievement),
- approach from the side of internal processes (product supply chain),
- strategic electorate approach (concentration on groups interested in the success of the organization, e.g. producer – suppliers, entity – banks).

Achievement of efficiency of production assets in an operating cycle requires efficient production management.

a) Efficiency of goal realization

Efficiency is referred to the level of execution of tasks adopted for the production system. Efficiency is a function of both production capabilities and the particularities of the task itself in the form of orders for particular products and services. Orders appearing in a company may be determined, random, or unknown (product not produced in the company).

Depending on the method of determination of the final goal there are staged and non-staged goals. In the case of production business results of business are more or less close to the main goal. If the main goal is achievement of a sales plan then the scope of assessment of execution level covers criteria such as: punctuality, quality, costs. From the client's point of view the first two criteria are important (assuming that the agreed price is not staged).

Example – Gradation of results of sales plan achievement in the aspect of timeliness and quality:

0 – delays in achievement (punishable),
1 – delays in achievement (agreed),
2 – lack of delays in achievement.

Timeliness T = (0, 1, 2), for:

0 – means lowest level,
1 – means middle level,
2 – the highest level.

Similarly for quality:

0 – reports on product damage of high importance in the period of warranty (product unfit for use),

1 – reports on product damage of low importance in the period of warranty (product fit for use),

2 – no reports on product damage in the period of warranty.

The level of efficiency of achievement of the plan of sales in the aspect of timeliness and quality is presented in Table 2.

Table 3 shows that highest priority in efficiency of achievement of the sales plan is timeliness (no delays in achievement) and quality (no reports of damages in the period of warranty). In numerous cases of achievement of the sales plan quality is of higher importance than timeliness. It means that item 4 in Table 3 is positive (grade – partially efficient*).

One may ask a question whether undertaking delivery should fulfill requirements of minimum efficiency in a form of efficiency point?

Table 2. Efficiency level of achievement of the plan
(*source: author's own work*)

No.	Timeliness	Quality	Goal achievement level	Delivery efficiency level
1	2	2	9	Efficient
2	2	1	8	Partially efficient
3	2	0	7	Inefficient
4	1	2	6	Partially efficient *
5	1	1	5	Partially efficient
6	1	0	4	Inefficient
7	0	2	3	Partially efficient
8	0	1	2	Inefficient
9	0	0	1	Inefficient

Table 3. Levels of goal achievement
(*source: author's own work*)

No.	Timeliness	Quality	Goal achievement level
1	2	2	4
2	2	1	3
3	1	2	2
4	1	1	1

On the basis of data from Table 4.3.4b one may assume:

- efficiency point = min{timeliness=1; quality =1},
- number of stages in the goal = 4.

Excluding from columns (2) and (3) value weights = 0, the result is a reduced Table 2.

From Table 3:

- minimum efficiency - goal achievement level: c = 1,
- efficiency point - goal achievement level: c_{min} = 2,
- full efficiency - goal achievement level: c = 4.

b) Efficiency of cooperation of production cells in an operating cycle

Efficiency of cooperation

$$KP = (\text{effective time: real time}) * 100\% \qquad (34)$$

The management of production cells must be adjusted to the characteristics of the production process. Spatial structures of production cells, meeting the criteria of rational deployment, will show following advantages [40, p. 180]:

- shortening of total production cycle and decrease in its costs (reduction of obsolete relocations, reloading, and manipulations),
- maintenance of the quality level of products and more efficient production methods.

Studies in numerous companies with mass type of production [48], indicated efficiency of cooperation of production cells at the level of 75 – 80% (Fig. 7). The flow of the process in cells of subject structure takes shorter time than in units of technological structure.

c) Efficiency of production assets facility maintenance

In traditional approach the measure of efficiency is the effective time of machine and equipment work available in the management of production capability. In a temporary approach, efficiency of facility maintenance is assessed on the basis of utilization of micro organizational breaks in the production process for maintenance and repair of machines and equipment assuming periodical maintenance breaks.

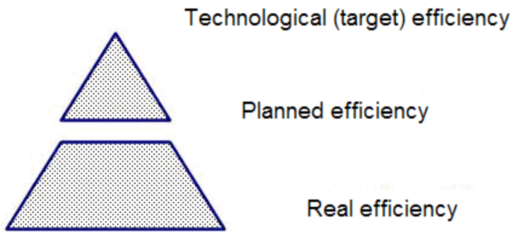

Figure 7. Division of efficiency of a workstation
(*source: author's own work*)

Other ratios are:

Achievement Ratio UR =
(possibility of achievement:
tasks to be performed) $*$ 100%

The ratio is a consequence of applying the economy rule in measure in the management of production assets.

4.3.5 Technological efficiency of a production station

Technology is the source of progress and increase in efficiency, affects the time of manufacturing – an important category in the process management. Time is an important factor of companies' competitiveness and may be utilized by: shortening of processes (timesaving), changes of existing processes to new ones (flexibility of time).

a) Technological efficiency of a production station

Technological efficiency – maximum achievable number of products at the output of process in ideal technological conditions (target efficiency of a production station)

According to SANDVIK company [60], proper application of tools (made of new tool materials) is able to improve efficiency by at least 20% due to higher speed of cutting and headway. Another benefit is higher quality of machined details (parts), a limited amount of waste and lower machining costs.

Increase in efficiency due to smoothing plates (an innovative product) is possible as a result of a small change to the corner of the plate, the speed of headway may be doubled while maintaining the finishing of the surface.

b) Production flexibility

Flexibility is associated with the ability for fast changes in processes enforced by the market. Mass production in, so called, „rigid" technical and technological systems does not meet the expectations of the market, which expects large selection of products produced in small batches and more varies expectations of clients.

According to J. Honczarenko [15, p. 224] technological flexibility of a lathe, in relation with the flexibility of the control system and flexibility of supporting equipment, comprises production flexibility of manufacturing systems. Production flexibility is a quality of a workstation expressing its ability to relatively easy and fast re-tooling and change of controls onto new products manufactured in small and varied series. An extended scope of manufacturing capabilities leads to machining products into ready-made items.

Production flexibility may be expresses as a quantity – by the number of various products, details, or production tasks, and qualitatively – sometimes transferring from the delivery of one task onto the other. There may be real and potential production flexibility. Benefits of a higher production flexibility are characterized by shorter times and an increase in real efficiency of workstations.

c) Automation of the processes

Automation contributes to the intensification of the manufacturing processes and leads to significant improvement in the technological level in all the elements of the process. The basis for improvement in efficiency resulting from automation is implementation of modern CNC production stations and technological processes. The development of automation on traditional technological processes would not result in improved efficiency. Automation plays an important role in better control of the time period [34, p. 59]. Shorter periods of time between orders from client to delivery of a ready product conditions efficient production.

Shortening of single process times, by concentration of tasks in a workstation leads to 5, or 6 fold increase in the station's efficiency.

Technological efficiency, production flexibility and automation of processes do not involve adjustment to changes only, but also utilization of their capabilities in order to utilize the modern market, which is difficult to recognize.

4.3.6 Technological efficiency of production cell

a) Efficiency of influence of technology on efficiency of production cell

Development of technology results in a possibility of decreased work consumption, and, as a result, in lower costs, and increased productivity of production stations of cell. The ratio takes a form:

$$S_{OTW} = \frac{\sum_{i=1}^{n} \Delta t_{j1} + \Delta t_{j2} + \dots \Delta t_{jn}}{T} \quad (35)$$

where:
S_{OTW} – efficiency of influence of technology on efficiency,
Δt_{j1}, Δt_{j2}, … Δt_{jn} . – decrease in work consumption in stations 1,2...n,
T – period of time (month, quarter, year).

A change in technology may comprise: the type of material, state of surface machining, shape, tools, equipment and process parameters. A decrease may affect not only the main time, but also the auxiliary time. In a longer period of time, lack of lower work consumption is a proof of low efficiency of influence of technology on efficiency.

b) Efficiency of settings and control of processes

The time of settings may be a productive time. Manual toll and object fitting on the stations and their control are time-consuming, non-repetitive activity, prone to errors of the operator. Technologically advanced machines are the source of income only when they work. An increase in productivity and accuracy requires reduction in stoppage times. It is possible as a result of application of measurement probes.

Application of measure probes eliminates the need for use of auxiliary equipment (costly special holders, measurement gauges). The measurement of the first piece in a production series, performed by manual meters, depends on the skills of the operator, however, the machined item's transfer onto the measuring machine may take a lot of time. Probes are able to control parts in the lathe in a shorter time.

Software of probes automatically compensates for deviations in the length and diameter of tools, the location of the part, and dimensional errors.

$$\frac{t_{ui} + t_{ki}}{t_{uo} + t_{ko}} < 1 \quad (36)$$

where:
t_{ui}, t_{ki} – setting and control time using modern measure tools,
t_{uo}, t_{ko} – setting and control time using traditional measure tools.

Systems of measurement probes enables elimination of costly stoppage time, particularly in CNC lathes and machining centers. Due to measurement systems of probes the setting and control time may be shortened by over 90% and increase the machining efficiency.

c) Utilization of technical diagnostics equipment

Technical diagnosis deals with assessment of the state of machines and equipment through direct examination of their qualities and indirect assessment of utility processes performed by them.

The purpose of utilization of technical diagnosis devices is reduction in stoppage time of production machines. The reasons for decreased technical state of machines are: post control faults, defective parts, loss of productive time, decreased efficiency, lower quality.

An important effect of utilization of technical diagnostics is the creation of basis of preventive maintenance and repairs.

The areas of utilization of diagnostic tools:

- verification of technical state of machines,
- classification and comparison of machines,
- testing and monitoring of the state of machines,
- forecasting necessary maintenance,
- checking new machines during sign-off examinations.

Facility management of machines with different wear structure requires utilization of technical diagnosis tools. Fast diagnostic assessment of the technical state of machines and equipment is the source of reduced stoppage time and maintenance costs, enables creation of planning preventive maintenance services.

4.3.7 Technological efficiency of a company

a) Efficiency of alternative technology development

Technology is a process of joining various types of resources in order to manufacture products which satisfy market needs. Basic resources comprise:

- technical resources (machines and production equipment),
- technological resources (technological knowledge, programs, projects of operating processes, possession of know-how),
- personnel resources (awareness of existence of alternative technology and readiness for their implementation, qualifications and competence of personnel).

Factors determining technological and personnel resources are cumulated. In division of manufacturing processes there are following criteria: type of process, technology and technological means applied during the manufacturing and organization of the process.

I. Durlik [11, p.148] claims that technology is not a constant category and is subject to constant development; it applies to used materials, tools and equipment, utilization of devices, methods of transport, methods of measurement and testing of products and method of maintenance.

In conditions of alternative technology it is advisable to assume that technical resources are adjusted to planned tasks, which determine needs resulting from influence of such factors as: efficiency, quality and time.

The basic criteria of alternative technology selection are usually: work consumption, material consumption, energy consumption, capital consumption.

Attractiveness of alternative technology results from the fact of elimination of simple works in favor of works requiring educated, skilled employees. The potential of alternative technology is reflected in a possibility of increased productivity, increased quality of products and processes, and also in decrease in costs.

Technological efficiency at the level of company comprises not only technical resources but the whole of technology. P. Drucker [9, p. 34], stresses that every technology is a system of concept and its technical aspects are rather the effect not the reason.

The technological effects of new solution are:

- an increase in the efficiency of a process due to a possibility of utilization of production machines with high concentration of operations,
- ensuring stable quality of products in the manufacturing phase,
- an increase in the efficient time pool of machine and equipment work,
- a shorter cycle of delivery of production orders,
- a possibility of utilization of production flexibility.

An example of technological efficiency is the concept of flexible manufacturing of EROWA company [59], for rational and future-oriented organization of unit and small batches production.

Influence of the level of automation upon utilization of lathes is presented in Fig. 8. There are numerous alternative technology solutions, including resignation from operations with low added value toward producer with higher technological level, or limitation to assembly with parts and components purchase from companies considered credible in terms of meeting technological and economical criteria.

b) Technological efficiency of processes development

Utilization of Advanced Manufacturing Techniques (AMT) requires efficient design of processes. Transfer from conventional production machines to numerically controlled meets limitations of software of technological processes. In this elaboration's author's opinion the efficiency of designing in Polish companies according to AMT criterion is at the level of about 50%.

c) Efficiency of knowledge and technological experience

Modern technology, except technology directly related to utilization of production assets, also covers knowledge, know –how, and experience cumulated in the process of human work. This technology part is described as immaterial technology [29, p. 383]. Knowledge and experience become an important advantage in international cooperation of companies.

In Polish companies immaterial technology is undervalued which results in falling productivity of numerous applied technologies. In numerous organized joint – venture companies technology is the value contributed to the share capital of the company.

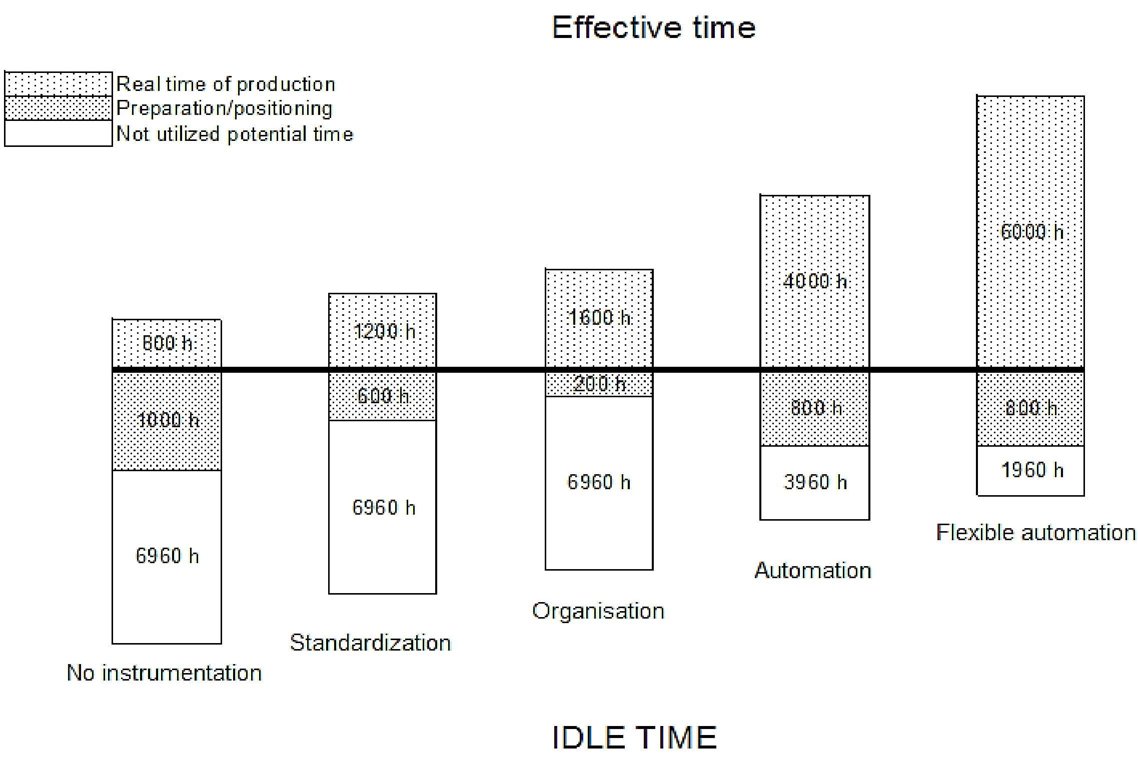

Figure 8. Annual utilization of lathes for various levels of automation
(*source: [15, p. 25], [59]*)

4.3.8 Economic efficiency of production assets at the company level

a) Overall and partial productivity

Assessment and improvement of productivity in the economic aspect productive utilization of all resources used in manufacture of products for the market requires supervision. P. Drucker [9, p. 57] assesses traditional ratios reflecting productivity as unclear and imprecise. According to the author, the most important factors for productivity are: time, composition of the production profile, composition of the production process and the organizational structure of the company.

Productivity – is a proportion of the production volume and sold in a given period to the quantity of used or utilized resources. This measure is to be interpreted as efficiency of utilization of resources of the production system. The productivity measures are divided into two groups [37, p. 31]:

- overal (general) productivity – the proportion of the total production to the total amount of used or utilized resources for their manufacture,
- partial productivity – the proportion of the total production to the amount of particular kinds of resources to the total amount of used or utilized resources for their manufacture.

b) Profitability of assets (ROA)

$$ROA = \frac{net\_profit}{total\_assets} * 100\% \qquad (37)$$

c) Ratios of investment in alternative technologies (technical and technological resources)

$$I_{AT} = \frac{N_{AT}}{P_{SP}} * 100 \qquad (38)$$

where:

N_{AT} – expenditure on investment in alternative technologies,

P_{AT} – revenues from sales of products.

Economic efficiency of assets at the company level, presents efficiency measured by productivity, profitability of assets and intensity of investment in alternative technologies.

4.3.9 Economic efficiency of assets of production cells

a) Efficiency of investment projects in alternative technology

Planning and delivery of investment products is related to a decision about purchase or manufacture of new assets, mainly of technical and technological resources. Methods of assessment of investment projects belong to the group of universal methods. Economic assessment involves an analysis and assessment whether the project multiplies invested capital and whether the rate of multiplication is high enough in the investment calculation period.

Universal methods include the following efficiency criteria ([7], [33] and [42]):

- the period of return of expenditure,
- book rate of return of expenditure,
- net revaluation value criterion,
- other (profitability ratio, IRR).

Developed methods of investment efficiency assessment are based on discount techniques. An example is the criterion of Net Present Value (NPV).

The concept of Internal Return Rate (IRR) involves determination of annual rate of multiplication of capital invested in a given project. It is a clear measure for an investor.

b) Labor costs of workstations in a production cell

The formula of cost calculation for one workstation ([55, pp. 73-81], [40, pp. 39-47]) lists in detail particular elements of fixed and variable costs.

$$K_{SP} = k_z + \frac{K_S}{F_{ef}} \tag{39}$$

where:
k_z – variable costs of a workstation,
Ks – fixed costs of a workstation,
F_{ef} – pool of time of a workstation.

The costs of a workstation decrease with higher charge with production tasks.

c) Economic efficiency of maintenance of production stations in cell

General formula takes the form:

$$E_{UR} = \frac{\text{actual expenditure}}{\text{planned expenditure}} \leq E_{URmax} \tag{40}$$

Actual and planned expenditure considers costs borne on maintenance, preventive and repair activities in a set scope.

4.3.10 Economic efficiency of a production station

a) Current value of a production station

- Net value

Net value (book value) = gross value – depreciation value

- Replacement value

Determined upon technical identification of facility or documentation and current prices of catalogue objects. The general formula takes the form:

$$\text{replacement value} = \text{Wb}\left(1 - \frac{Z_F}{100}\right) \tag{41}$$

where:
Wb – gross value according to catalogue prices of a facility compared with the valued facility,
Z_F – physical wear of facility (%).

- Market value

Value of technical object achievable on the industry market. The general formula takes the form:

$$\text{market value} = \text{Wb}\left(1 - \frac{Z_F}{100}\right)\left(1 - \frac{Z_E}{100}\right) \tag{42}$$

where:

Z_F – physical wear of facility (%).

Z_E – economic depreciation of facility (%).

The comparison of the values gives a view over the fall/increase in the useful value and its influence on quality and timeliness of production.

b) Economic efficiency of increased efficiency of a production station

An increase in efficiency of a station results from a need for achievement of production tasks. Factors affecting efficiency are: technical facility, tools, devices, measuring equipment, parameters of a work process, facility operator. The reference point is the stability of particular operations. Each operation with technical and organizational flaws of resources that execute it is potentially unstable, threatening a drop in efficiency and decreased quality of production.

The following formula of machine and equipment efficiency ratio OEE, may be used for establishment of economic efficiency of increased efficiency ([27, p. 20], [51, p. 56]):

$$\text{OEE} = \text{availability} * \text{efficiency} * \text{quality} \tag{43}$$

The schedule of the painting and anti-corrosion process of car bodies

The main process comprises main following, subsequent operations (activities):

1. transport with possibility of temporary waiting
2. preparation of bodies for chemical processing and chemical processing of bodies
   a) spray washing,
   b) submerge washing,
   c) activation,
   d) phosphatizing,
   e) passivation,
   f) submerge and spray washing,
3. transport of bodies to cataphoretic unit
4. cataphoretic submerge painting
   a) spray washing I and II
   b) submerge rinsing in demineralized water
   c) spray washing with demineralized water
5. transport of bodies to cataphoretic drier
6. drying and cooling of cataphoretic coat
7. transport of bodies from cataphoretic cooler with waiting capability (storing of bodies)
8. storage after cataphorezis
9. cataphoretic processing cabin
10. transport of bodies to the sealing cabin
11. joint sealing cabin
12. mastic spray cabin (PVC)
13. mastic coat drying and cooling (PVC)
14. transport and preparation of bodies for priming paint spay
15. electrostatic priming coat spray cabin
16. priming coat drying
17. transport of bodies from priming drier
18. priming coat cooling
19. transport of bodies from priming cooler
20. priming processing cabin
21. transport to the base cabin
22. electrostatic spray of base coat cabin and intrazone base drying
23. colorless paint spray cabin
24. colorless paint coat drying
25. transport of bodies from paint drier to inspection cabin with possibility of storage of bodies
26. inspection cabin
   a) inspection,
   b) polishing and minor repairs,
   c) polishing of bodies
27. transport of bodies from inspection cabin to assembly

Auxiliary process

28. transport of bodies to touch up cabin
29. touch up body preparation cabin
30. manual base spray cabin
31. intrazone base drying
32. manual clear lacquer spray cabin
33. clear lacquer coat drying and cooling
34. transport of bodies to inspection cabin

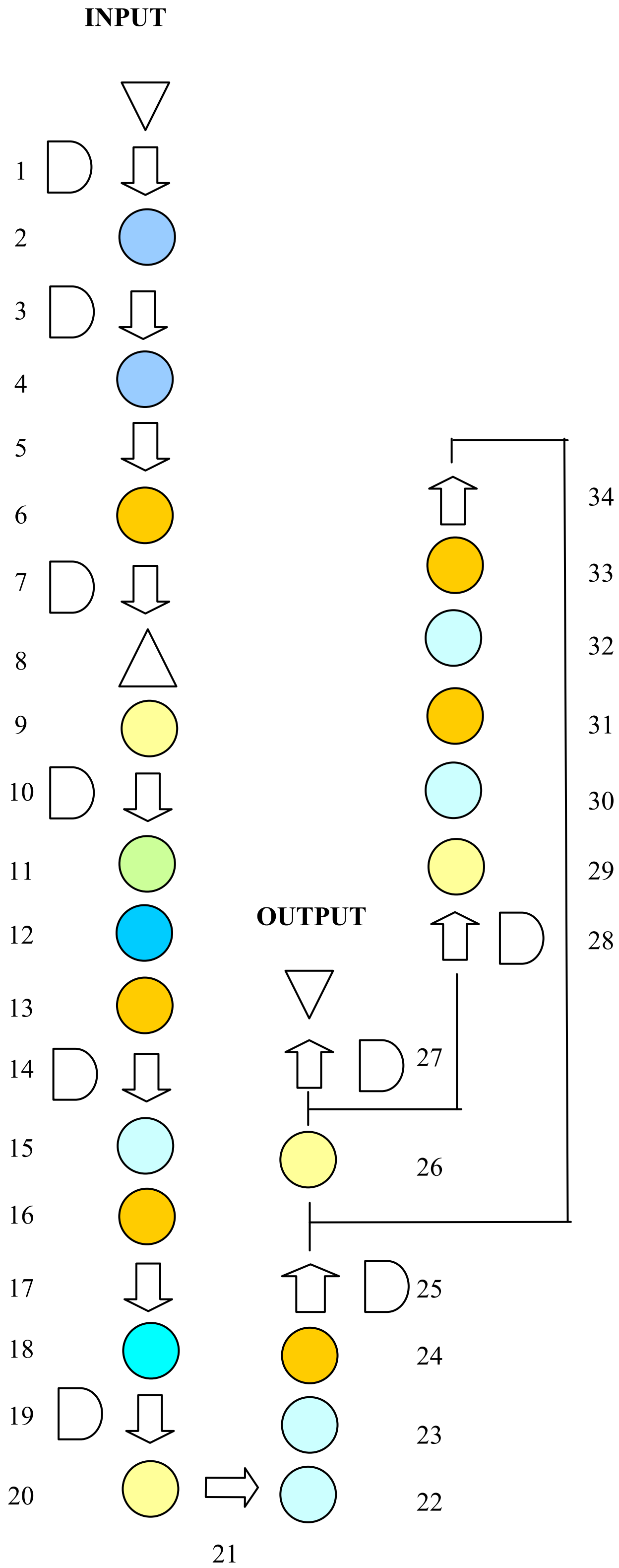

Figure 9. Scheme of painting and anti-corrosion car body process (*source: [58]*)

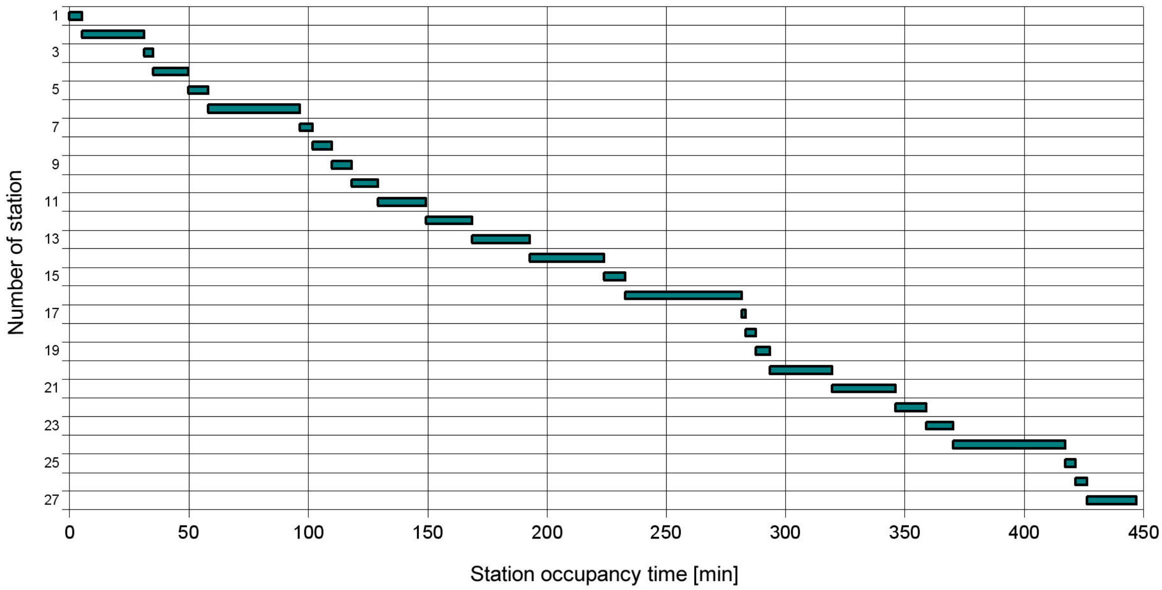

Figure 10. Schedule of the process of painting and anti rust of bodies
(*source: [58]*)

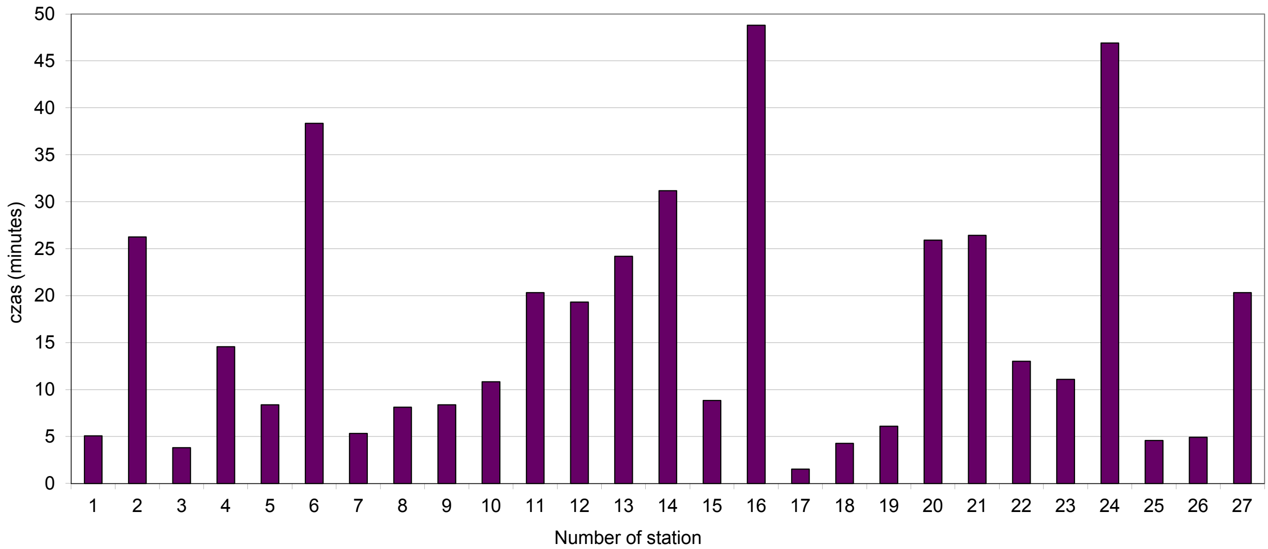

Figure 11. Distribution of workload on body painting and anti-corrosion line stations
(*source: [58]*)

c) Economic efficiency of alternative production station

The search of alternative solutions results from a need of decreased production costs. Such solutions comprise:

- stations outside the company,
- purchase of a new machine (a machining center instead of a CNC lathe) with modern production equipment,
- radical change in the technology of manufacturing.

The economic calculus in this type of ventures is one of traditional methods of assessment of economic efficiency.

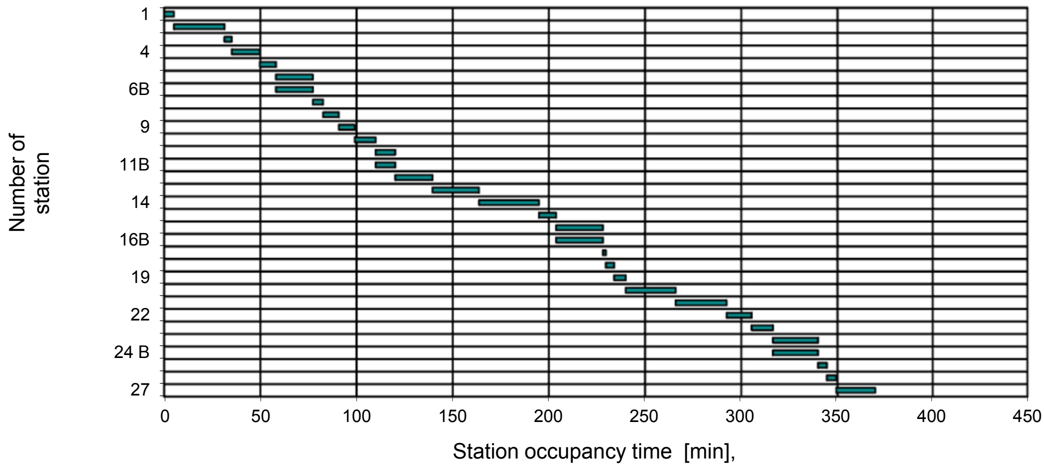

Figure 12. Schedule of the painting and anti-corrosion protection process with parallel running of coat drying operation
(*source: [58]*)

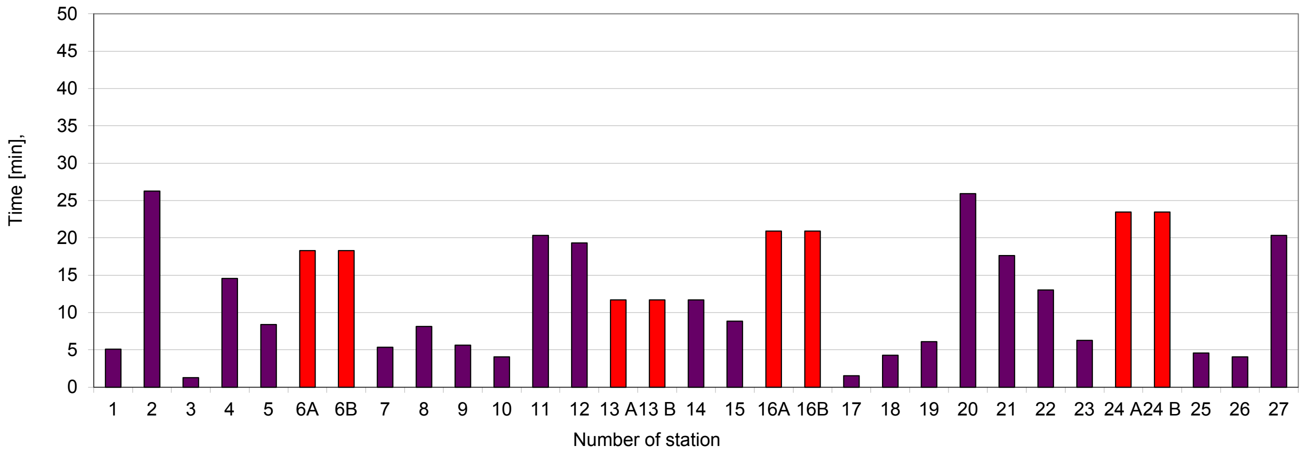

Figure 13. Distribution of load on workstations of the body painting and anti-corrosion protection line with parallel stations of coating drying
(*source: [58]*)

4.4 The project of production process improvement

The project of process improvement is designed to optimize the technological process in the view of meeting current technological, technical, environment protection, safety, and in particular, economic requirements.

The scheme of execution of the painting and anti-corrosion protection process of car bodies is presented in Fig. 9 and Fig. 10.

The technological process is delivered on a production line in a continuous manner. The technological speed is adjusted for every station.

An important goal is an increase in the efficiency process. The schedule of painting and protection process is presented in Fig. 10 and Fig. 11.

The cycle of the process is 446 minutes. The distribution of load on stations is uneven (Fig. 11). Stations no. 6, 16, 24 are the critical knots in the process. In order to shorten the painting cycle it is proposed to run parallel stations of drying: coating, primer, and sealer, and application of sealers.

A new schedule is presented in Fig. 11 and Fig. 12. The time of production line filling is about 370 minutes. In car production conditions it is a significant shortening of time.

Distribution of load on painting and anti-corrosion protection workstations with parallel stations is presented in Fig. 12 and Fig. 13. One must remember that without drying a proper lacquering surface will be created.

In order to balance the continuity of the process and compensate for differences in speed of conveyers, one must use the intra-operation storages.

In order to further improve the body painting process one must look for new technological materials which may affect the drying time, and as a result, increased efficiency.

5 Summary

Production assets management in a company is a traditional function, which in the period of transformation lost its parallel role toward the marketing and finance function. Higher machine efficiency contributes to improvement of work efficiency. Production assets efficiency is limited to the economic criterion, often seen in business only in the statistical dimension.

Experience of exploitation of advanced productions systems indicates that the factor decisive of efficiency is available time, not exploitation costs.

A new concept of studies on efficiency results from adoption of an assumption, that development of production systems, including technology production, conditions production assets efficiency.

The main goal of the new concept is increased production assets efficiency in a company.

Achievement of the main goal, due to the scale of problem, assumes separation of three levels of efficiency: 10 – the company, 20 – the production cell, 30 – the production station, and its three different assessment criteria: economic, technological, operating.

At the level of production station operating efficiency has the following elements: reliability, efficiency, utilization of the production station.

A measure of operating efficiency of production cells are the ratios: efficiency of production stations, production capabilities, utilization of production capabilities.

The basic measure is the production capabilities.

Efficiency was selected as the main operating criterion at the company level, i.e. the ability to reach a set goal of the final activities.

Technological efficiency at the level of the production station is expressed by the ratio of technological efficiency, at the level of production cell the efficiency of technology influence on efficiency of production cell. At the company level, the alternative technology development ratio was taken.

Economic efficiency is determined by the factors: at the workstation level – economic efficiency of alternative production station; at the level of production cells – economic efficiency of designing alternative technology; at the company level – total and partial productivity.

The evolution of structural changes in Poland positively affected the efficiency of companies and the privatization process also covered production assets. Investment and modernization expenditure spent on production assets, contributed to implementation of modern technology and increased efficiency and the quality of the production process.

A new concept of study on production assets efficiency in a company results from development of technology and production systems. Gradual implementation of new technologies and modern processes of manufacturing products requires in companies requires increasing production assets efficiency.

The evolution of studies on the fixed assets management efficiency there are three periods:

- fixed assets management efficiency (years 1970 - 1989),
- restructuring of the non-current assets (years 1990 - 2000),
- fixed assets management (from 2000 and now).

The process of utilization of fixed assets is limited by technological efficiency and stoppages caused by various reasons.

A significant role of financial statements in Poland after 1990 and new importance of non-current assets as a part of company value, contributed to an analysis and assessment of new ratios of efficiency.

In a new concept of studies on production assets efficiency there are:

- operating efficiency,
- technological efficiency,
- economic efficiency

defined at the level of a production station, production cells, or a company.

The main goal of the new concept is to increase the production assets efficiency. Increasing the production assets efficiency is burdened with the technical and market risks. The rate of exchange of production machines depends on the lifetime of the technology. Efficiency measurement is an instrument of supervision, but a tool supporting management in the company.

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CLOUD BUSINESS INTELLIGENCE FOR SMEs CONSORTIUM

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Abstract: Business Intelligence technology for over 20 years is the market leader in analytical processing of data. As numerous market researches demonstrate Business Intelligence has substantial affect on global competitiveness of enterprises and on the stability of their position in the market, which is particularly important in times of economic downturn. Although main users of this technology are large companies and corporations, software vendors are still looking for solutions that are also available for the SME (Small and Middle Enterprises) sector and non-profit enterprises. One option available recently is possibility to use Cloud Computing environment. The article considers the opportunities and risks posed by the organization of Cloud Business Intelligence system on the example of using it in SME sector.

Keywords: Business Intelligence technology, Cloud Computing framework, Cloud Business Intelligence concept, SMEs, opportunities and limitations.

1 Introduction

The characteristic feature and the determinant of Business Intelligence (BI) effectiveness is the degree of its integration at the level of concept, organization and functioning ([2], [3]). This integration is hindered by locational, organizational and functional dispersion of data sources and system users. In the consideration case of the SME sector there is also the problem of having to take advantage of the high level of support in the design, construction as well as maintenance of the BI system. With the need to ensure high effectiveness and efficiency of its use. Due to the complexity of BI and the need of finding a solution ensuring optimum of the integration in distributed organization structure, it seems reasonable to propose architectural solutions based on Cloud Computing (CC) framework.

If it treats CC as the development of earlier former and concepts of services such as: grid computing, utility computing, distributed computing, visualization, and above all SaaS and outsourcing, that attempt to integrate these solutions with BI is being developed for several years in researches papers (e.g. [2], [8], [11] and [32]). All of them are carried out for long time with varying degrees of success, but each of them should be regarded as fragmented in comparison to all the needs of the SME sector. Therefore this article presents the concept of integration BI solution in CC environment, dedicated for SMEs enterprises. The purpose of the construction of such a solution is making available BI solutions to SMEs sector, taking into account full package of economic, organizational and functional constraints in the implementation and use of them. This objective can be expressed by the research question to which the answer will be sought:

How the restrictions in implementing of Business Intelligence can be eased or eliminated through using Cloud Computing technology?

The answers to the above question was subordinated to the structure of the presented article. In section 2 of the article possibilities and limitations of BI technologies are discussed. Properties and specifics of CC technology are presented in section 3. Varieties variants of the integration of BI with CC concept are described in section 4. In section 5 the proposal for Cloud Business Intelligence (CBI) implementation concept for SMEs are placed. The article ends with summaries and conclusions in section 6.

2 Specificities, possibilities and limitations of Business Intelligence technology

Business intelligence is gathering, managing, analyzing, and sharing of information in order to gain insights that can be used to make better decisions [14]. The most important purpose of BI is to provide business managers and analyzers the instruments required conducting analysis [30].

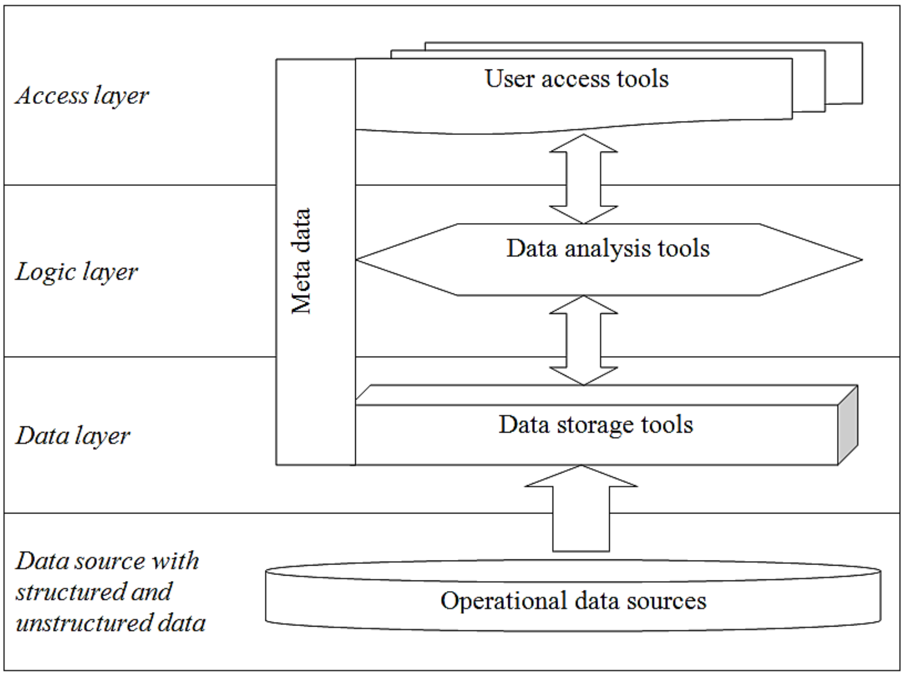

Figure 1. Conceptual three-layer BI architecture
(*source: based on [2]*)

It can extract and organize available information to help users to make timely and accuracy decisions to promote management, marketing and company development by fully using present business information and modern techniques [35]. Cui et al. [9] consider BI as way and technique of developing business performance by supplying influential supports for managerial decision maker to let them to have liable information at hand. BI tools are viewed as technology that facilitates the effectiveness of business function by giving an enhanced value to the enterprise information and therefore the way this information is used. BI can also improve financial performance and service, it allows to sustain the competing merit and to bring more economics benefits for company through analyzing and holding new opportunities and finding potential threats.

These all is done through interactive access to existing and historical information, circumstances, and executions, which all supply perception in the organization and makes capable intelligent decisions. BI can be served as architecture, tool, technology, or system that collects, stores, and analyses data by analytical tools, facilities reporting, querying and delivers information that eventually lets organizations to enhance decision-making [30]. The BI systems contribute to enhancement and precision of information flows, and knowledge management and they make capable organizations to ([20], [25]):

- pursue profitability of their goods sold,
- analyze costs,
- monitor incorporated environments,
- detect business anomalies and frauds.

The basic architecture of BI contains three layers (see Fig. 1): data, logic and access. Data layer is cleaning and transforming useful data, extracted from many different data sources. Then, after ensuring its accuracy, loading them into data warehouse, data mart or data store. Logic layer is analyzing data by suitable queries and analysis tools, data mining tools, OLAP tools, etc. Finally, access layer presents the results of logic layer for supporting management decisions. It is realized with graphical user interface, analytical application or web portal.

According to IDC[1] researches the market of Business Intelligence is now the fastest growing IT sector and one of the few that have experienced growth in own value during crisis years.

[1] IDC (International Data Corporation) - one of the biggest companies involved in researches of the global ICT market. It deals with the preparation of sectoral researches, is a strategic advisor to ICT projects. The main its goal is to provide analysis on current and future development trends in individual sectors of the ICT market.

According to IDG[2] and SAS Insitute[3] experiences [36] it happens because enterprises see in this IT tools category a chance to gain competitive advantage (80% of surveyed companies) and overcome the effects of economic slowdown (70% of surveyed companies).

Mentioned SAS research was conducted in 2009 among 80-plus medium and large Polish companies. It showed that the most important effects of the Business Intelligence system implementation are [36]: higher quality and better availability of management information (62% of respondents), the possibility of optimization and efficiency improvement of business processes (60% of respondents), a support in reasonable reduction of operating costs (44%), an increase in management efficiency (40% of respondents), an increase of revenue (20% of respondents), an improved relationships with customers (16% of respondents), an increased financial transparency within the enterprise (10%). Surveyed entrepreneurs are using or have used Business Intelligence tools in the management of [36]: finance (56%), strategy (38%), customer relationship (38%), supply chain (16% of respondents), production (16% respondents), marketing (12% of respondents), human resources (8% of respondents).

Although the survey was conducted among medium and large enterprises, providers of Business Intelligence solutions said that for the same reasons the SME sector enterprises buy those solutions more and more often [10, p. 16-26]. This was possible because more and more software producers begin to see the needs of SMEs, now their products are more financially available for this sector. However, as shown in author's survey results conducted among 150 dental clinics of the SME sector, the most important restrictions of the use of IT tools in supporting decision-making are [28]:

- lack of technical knowledge in the field of IT solutions decision-making support,
- lack of trained personnel, to whom implementation and maintenance of such solution could be addressed,
- limited knowledge of business management (management is mostly based on intuition and own experiences),
- limited financial resources which could be used in this type of investment,
- limited and often insufficient for multidimensional analysis the number of collected operational data resources.

Taking into account those limitations will be sought the such organization of BI system that provides the possibility of its implementation in the identified group of SMEs.

3 Characteristics of Cloud Computing technology

CC is a style of computing where massively scalable IT-related capabilities are provided "as a service" using Internet technologies to connect multiple external customers [26]. The name "cloud" is an acronym of: "Common, Location-independent, Online Utility that is available on Demand" [7].

CC refers to both - applications delivered as services over the Internet and the hardware and systems software that provide those services. It is emerging model of computing where hardware in large data centers can be dynamically provisioned, configured, and reconfigured to deliver services in scalable manner [15]. Summarizing the cloud model presents three new dimensions for computing [1, p. 1]:

- the infinite computing resources available on demand, thereby eliminating the need for cloud computing users to plan far ahead for provisioning.
- the elimination of up-front commitment by cloud users allowing to start from small and next increase hardware resources only when there is an increase in their needs.
- the ability to pay for use of computing resources on a short-term basis as needed (e.g., processors by the hour and storage by the day) and release them as needed, thereby rewarding conservation by letting machines and storage go when they are no longer useful.

[2] IDG (International Data Group) – The international company dedicated to the provision of multimedia and marketing services, organization of conferences and meetings, scientific publishing, market research, consultancy of design and implementation and propagation of knowledge about modern IT technologies.

[3] SAS Institute – international IT corporation classified as Business Intelligence market leaders.

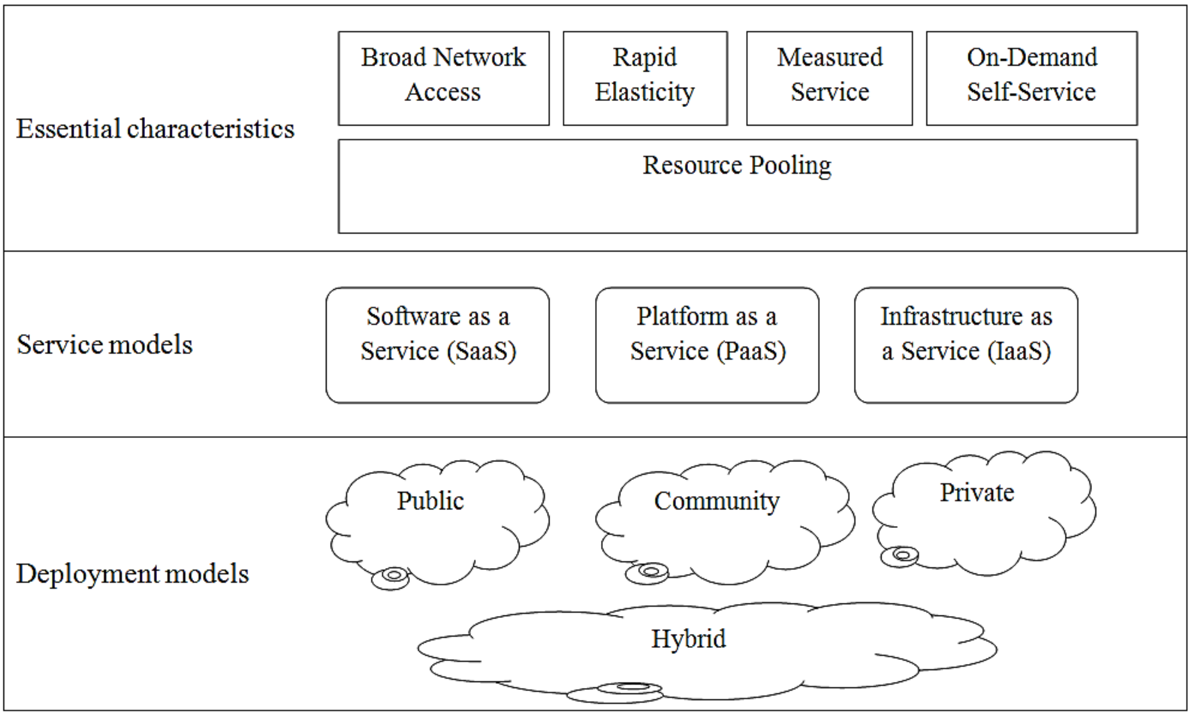

Figure 2. Visual model of NIST of Cloud Computing definition
(*source: based on [4]*)

The cloud model is composed of five essential characteristics, three service models, and four deployment models (see Fig. 2).

These five characteristics include [4]:

- broad network access - all computing resources are available over the network (e.g. internet) and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and personal digital assistants),
- rapid elasticity - capabilities can be rapidly, in some cases automatically, and elastically provisioned; for consumers these capabilities are unlimited and can be purchased in any quantity at any time,
- measured service - cloud systems automatically control and optimize resource use by leveraging a metering capabilities at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts); resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer of the utilized service,
- on-demand self-service – clients can ourselves control computing capabilities, such as server time (CPU time) and network storage, and as needed automatically change them (conveniently by self serve method) without requiring human interaction with each service's provider,
- resource pooling - the cloud service provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.

Three service models contain [4]:

- Software as a Service (SaaS) – the consumers use the provider's software applications, running on a cloud infrastructure,
- Platform as a Service (PaaS) – the consumers have access to the cloud infrastructure using programming languages and tools supported by the provider,
- Infrastructure as a Service (IaaS) - the consumers get provision to processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications.

The type of CC model is related to division of level of management and responsibility between user vs. service provider (see Table 1).

Table 1. Division of management and responsibility between user vs. service provider
(*source: based on [13], p. 19*)

Self-managed/ self-owned	IAAS	PAAS	SAAS
Application	Organization has control	Organization shares control with vendor	Vendor has control
Virtual machine	Organization shares control with vendor	Organization shares control with vendor	Vendor has control
Server	Vendor has control	Vendor has control	Vendor has control
Storage	Vendor has control	Vendor has control	Vendor has control

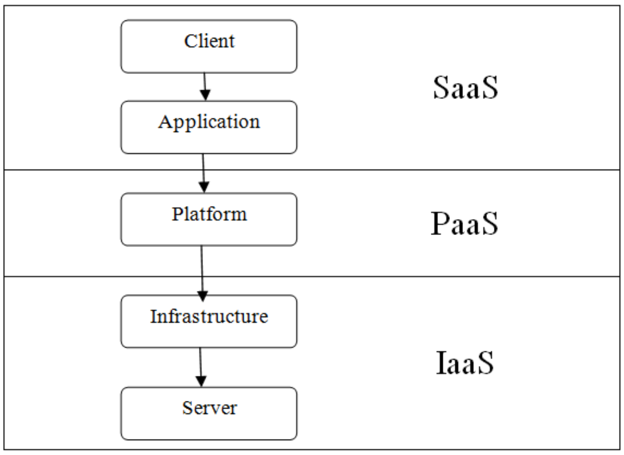

Figure 3. Relations between architecture layers and service models in CC
(*source: based on [24]*)

These three types of models handle five layers of cloud computing architecture (see Fig. 3):

- server layer - the base layer comprised of servers, hardware and software, present in different locations interconnected with high speed network connections,
- infrastructure layer - the layer which contains infrastructure as a service, provided by the service provider in the form of virtual machines or operating systems,
- platform layer - such capabilities as developing and testing applications without investing into additional hardware or software, services for team collaboration, web services integration, operated online desktop-like environment, etc.,
- application layer - access to applications without installing and updating any software on the computers locally,
- client layer - the final layer comprised of both hardware and software required in the cloud network for correct functioning.

Finally, the four deployment models are [4]:

- private cloud - the cloud infrastructure operates solely for an organization,
- community cloud - the cloud infrastructure is shared by several organizations and supports a specific community of these organizations with common mission, strategic objective, security policy, etc.,
- public cloud - the cloud infrastructure is available to the general public or a large industry group and is owned by an organization selling cloud services,
- hybrid cloud - the cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load-balancing between clouds).

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Core Cloud Services	Software as a Services (SaaS)/Applications:			Cloud User Tools		
	Citizen Engagement:	Government Productivity:	Government Enterprise Applications:	Application Integration:	User/Admin Portal:	Reporting and Analytics:
	Wikis/Blogs	Email/IM	Business Application	APIs	Customer /Account Management	Analytic Tools
	Social Networking	Virtual Desktop	Core Mission Application	Workflow Engine	User Profile Management	Data Management
	Agency Web Site Hosting	Office Automation	Legacy Application	EAI	Order Management	Reporting
	Platform as a Service (PaaS):			Mobile Device Integration	Trouble Management	Knowledge Management
	Databases	Testing Tools	Developer Tools	Data Migration Tools	Billing Tracking	
	DBSM	Directory Services		ETL	Invoice Tracking	
	Infrastructure as a Service (IaaS):				Product Catalog	
	CDN Storage	Web Services Virtual Machines	Server Hosting			

Cloud Services Delivery Capabilities	Service Management and Provisioning:				
	Service Provisioning	SLA Management	Performance Monitoring	DR/Backup	Operations Management
	Security and Data Privacy:				
	Data/Network Security	Data Privacy	Certifications and Compliance	Authentication and Authorization	Auditing and Accounting
	Data Center Facilities:				
	Routers	Firewalls	LAN/WAN	Internet Access	Hosting Centers

Figure 4. Practical example of CC technical framework
(*source: [12, p. 4]*)

All above elements form the framework of CC solution. The example of this framework is illustrated below at the Fig. 4. Practical example of CC technical framework (Fig. 4) provides a high-level overview of the key functional components for cloud computing services for USA Government. The cloud computing framework is neither an architecture nor an operating model. The framework is a functional view of the key capabilities required to enable cloud computing technology. It consists three major categories of cloud services:

- Cloud Service Delivery Capabilities – core capabilities required to deliver cloud services,
- Cloud Services – services delivered by the cloud,
- Cloud User Tools – tools or capabilities that enable users to procure, manage, and use the cloud services.

The horizontal functional areas represent the core of computing capabilities that enable different levels of cloud computing. The vertical functional areas illustrate the management and business capabilities needed to wrap-around the core components to enable business processes with cloud computing. For example, reporting and analytics offer the ability to perform key reporting and business intelligence analytics and therefore are not core cloud computing components.

Table 2. Benefits in the practical example of CC technical framework
(*source: [18, p. 3]*)

Type of benefits	Current environment	CC framework benefits
Efficiency	– low asset utilization (i.e. servers utilization < 30%)	– improved asset utilization (i.e. servers utilization increase to 60-70%)
	– fragmented demand and duplicative systems	– aggregated demand and accelerated system consolidation
	– difficulty to manage systems	– improved productivity in application development, application management, network, and end-user applications
Agility	– years required to build data centers for new services	– more responsive to urgent agency needs
	– months required to increase capacity of existing services	– instantaneous increases and reductions in capacity
Innovation	– burdened by asset management	– shift focus from asset ownership to service management
	– decoupled from private sector innovation engines	– tap into private sector innovation
	– risk adverse culture	– encourages entrepreneurial culture

However, analytics offer significant business capabilities that can harness the power of the data that will reside within the cloud computing environment. For this project benefits shown in Table 2 were identified.

Among the most frequently mentioned benefits of CC technologies are [27, pp. 10-11]: scalability, easy implementation, skilled practitioners, frees up internal resources and quality of service. However, while mentioning undoubted advantages of cloud computing we cannot forget about its risks and faults. Gartner Institute[4] lists seven major threats [26]: data risk, regulatory compliance, data location, data segregation, recovery, investigative support and long-term viability. Many works are devoted for research of risk in implementations of CC framework, e.g. in works of Committee of Sponsoring Organizations of the Treadway Commission (COSO) are exchanged [13, pp. 4-5]: disruptive force, residing in the same risk ecosystem with other tenants of the cloud, lack of transparency, reliability and performance, vendor lock-in and lack of application portability or interoperability, security and compliance, high value of cyber attack, risk of data leakage, IT organizational changes and cloud service provider viability.

The above analysis shows that although the CC technology implementation is fraught with risk, and certainly is not the solution for everyone, it also creates an opportunity to increase efficiency and integrity in BI solutions. The conception of building a BI system in CC technology is shown in the next section.

4 Cloud Business Intelligence – scenarios and strategies of system organization

The diverse constructs introduced above lead to a framework that can help with identifying, combining, and evaluating potential services. This framework is visualized in Fig. 5.

The link to all possible variations is an umbrella of general provider and contract related issues. As in all outsourcing agreements, it needs to be thoroughly tested whether the provider is trustworthy. Besides, the contractual agreement has to pinpoint CC promises of high availability, data security, flexibility, scalability, and reliability in form of defined service level agreements.

The next building block in the framework is the actual composition of the service. This can be achieved by specifying the applied granularity on the tool layer (solution, component, or web-service) and by defining the subsumed BI services with the help of the dimensions component, business specificity, and life-cycle phase.

[4] Gartner Institute – is international research institute focused on analyses of IT market.

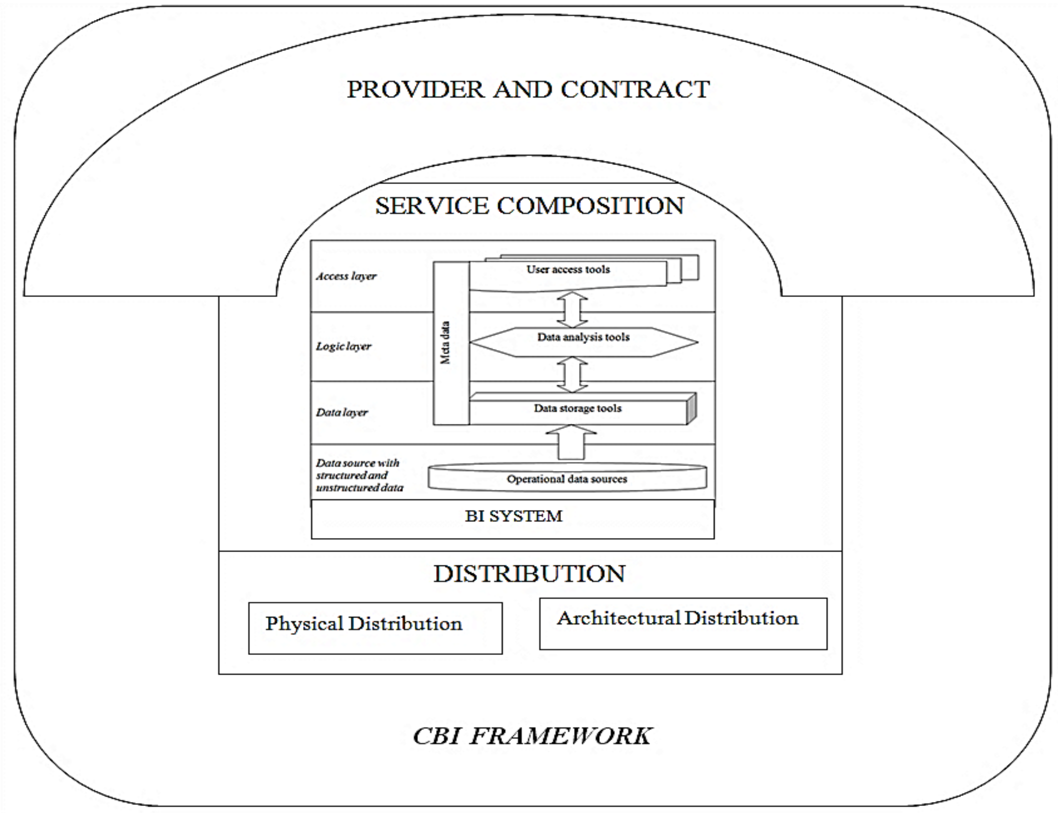

Figure 5. Cloud Business Intelligence framework
(*source: [3, p. 1535]*)

Next CC aspect is the distribution. In BI solutions it contains: physical distribution (with the options of confining the data storage locations to the premises of the provider, to keep the data in a network of business partners, or to freely distribute it on Internet level) and the architectural distribution (with the extremes of an end-to-end service provider on the one side and a best-of-breed solution composition that combines services of several providers on the other).

Finally intended benefits have to be reflected upon. This can refer to classical cost based outsourcing rationales or to harnessing the qualitative traits of CC approach (introducing flexibility, scalability, performance, or additional functionality). Besides, there might be informational benefits (through add-on data integration services from the provider) or even transformational effects (by adding new capabilities).

4.1 Cloud Business Intelligence scenarios

Starting from the above characteristics can suggest possible scenarios for implementing BI solutions in CC. The composition of the three basic elements: contract, service and distribution creates suitable scheme of (Fig. 6, [3, p. 1536]): add-on services scenario, tool replacement scenario, solution provision scenario, business network scenario, best-of-breed scenario, BI mashup scenario.

The add-on services scenario refers to the inclusion of selected functional blocks from CC into BI infrastructure. Examples are components for web information retrieval, web services for preprocessing qualitative data (e.g. with object or face recognition algorithms), data visualization components etc. By applying grid technologies on the provider side, even computation heavy features become affordable. The approach is relatively risk free because of its small scale.

In the tool replacement scenario CC idea is applied to complete software tool, e.g. web portal, data mart or OLAP tool. The tool replacement conforms to the SaaS idea with possible benefits being a more favorable cost structure, higher service levels and performance (e.g. when applied to complex analysis tools). Depending on the type of tool that is moved to CC, this can become a critical cut into existing BI infrastructure with far reaching implications. Long term contracts with trusted vendors and a curbed data distribution seem suitable for this scenario.

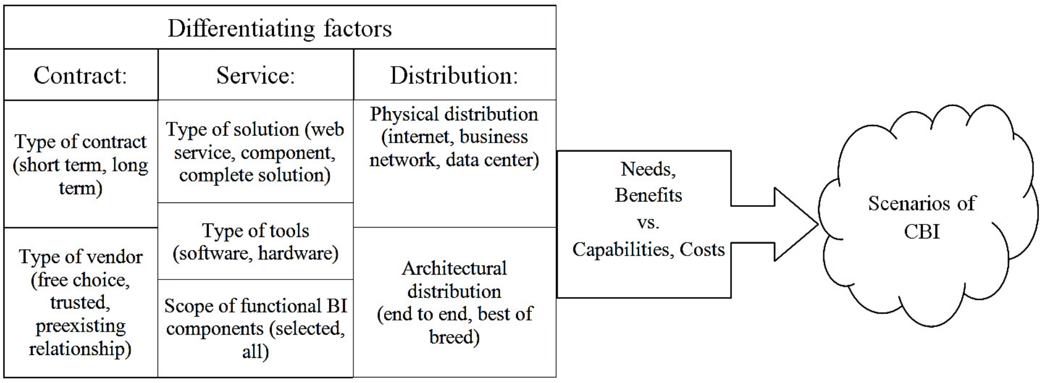

Figure 6. Cloud Business Intelligence scenarios
(*source: based on [3, p. 1536]*)

The solution provision scenario comes close to a classical ASP (Application Service Provider) agreement with the provider being responsible for the complete hardware and software of an isolated solution – end to end and across all layers. It has disadvantages as it possibly introduces a centrifugal force to an integrated BI infrastructure. It might however be suited for special purpose solutions that need to be set up fast, e.g. for a time-restricted data mining project or for piloting new types of applications.

The solution provider scenario comes from and acts within the confines of a business network. This might be a B2B marketplace, a franchise operation, a supply chain etc. The service provider is preferably a central and neutral partner in the network and provides solutions geared at the different members. CC aspect lies in the physical abstraction with the provider infrastructure being virtualized, i.e. by connecting the data center resources of the network members. This scenario also allows for information integration benefits.

The best-of-breed scenario is the idea of pushing the tool replacement scenario further up to the point where all components of the BI infrastructure are delivered by external providers. The result is a fully virtualized BI infrastructure that reaps all benefits of a best of breed resource allocation. Unfortunately this scenario is currently still hampered by the Cloud capabilities of some BI tools.

The BI mashup scenario assumes a freely composed BI solution sourced from a global Internet market space. Compared to the best-of breed scenario, it adds a finer granularity as well as a stronger focus on combinability and quick development (the development life cycle phase). The additional benefits primarily lie in its extreme agility.

4.2 Cloud Business Intelligence integration strategy

Integration of solution needs a very well defined strategy which provided CC capabilities. Success of the implementation depends on the existence of a service oriented strategy at the level of the organization, which would provide the necessary infrastructure for the CC implementation [16]. Based on recent research on integration of BI solution and transition it to CC ([23], [19]) it proposes the following strategy of implementation of solution in six stages (see Fig. 7).

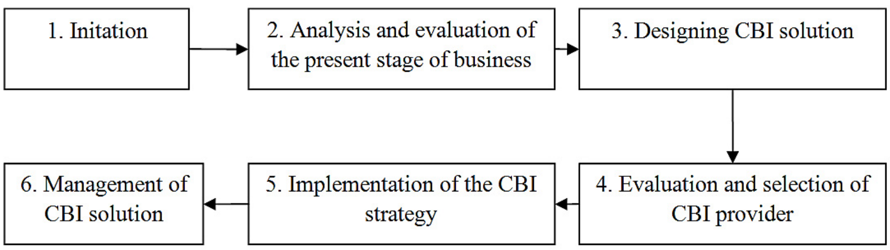

Figure 7. Stages of Cloud Business Intelligence integration strategy
(*source: [22, p. 44]*)

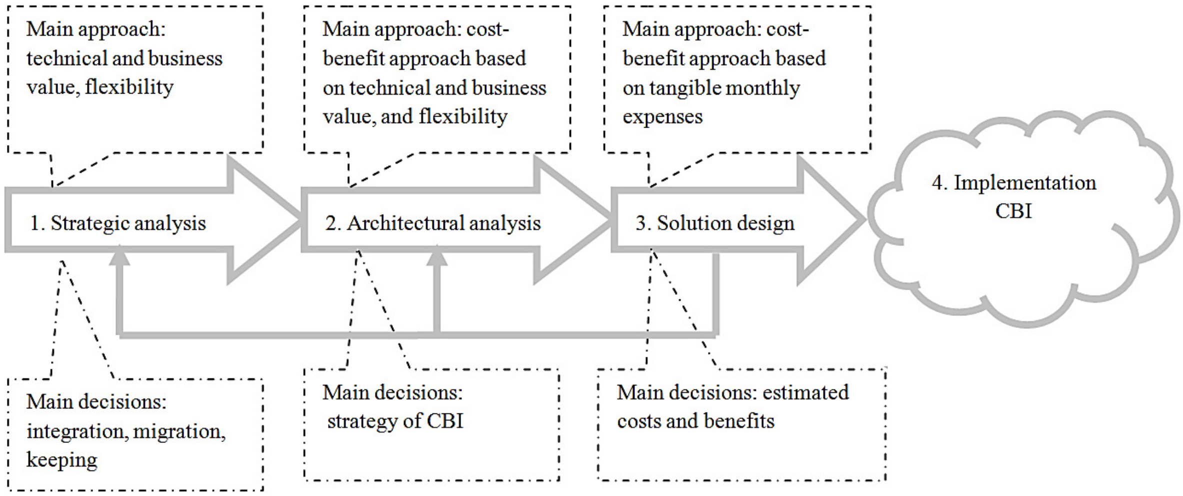

Figure 8. Decision model for choosing CBI solution
(*source: based on [22, p. 47]*)

Initiation stage includes identifying and setting the hierarchy of business objectives, assessing the budget needed to use solution, setting up the work team, the deadlines and the resources for implementation and maintenance. Also, within this stage the business users that will perform solution management must be identified and involved in the following stages. Strategy work team have to include IT personnel as well as business management. They will communicate with internal and external stakeholders concerning objectives, progress, costs and benefits for each cloud project.

For the success of strategy it is essential to identify resources used in the daily operations and in establishing the internal operation base. Also, at the level of the organization, the present needs and possible opportunities of solution have to be identified. Therefore, the present stage of business has to be analyzed and evaluated both from an internal and an external perspective of the business, putting the stress on the culture and value of business, on important business processes and business infrastructure. Evaluation of business infrastructure involves, among other things, analysis of management and security of applications, data storage, finding and classifying data.

Designing of solution may be achieved through the following steps:

- mapping BI requirements and IT culture according to one of CC models - the key for the success of strategy is obtaining the correct combination between the cloud and internal development for taking advantage of both solutions. Transition to the cloud may be achieved gradually, and the software provision models will coexist for a period of time,
- identification and evaluation of the different plans of verification of the benefits of solution - for the evaluation of different plans, the types of criteria determining the opportunity of solution in a specific situation must be analyzed, such as: level of personalization of data sources; priority of BI solution on the list of internal IT projects; considerations regarding security, risks, regulatory and privacy issues; development of organization and applications,
- identification of the main providers that meet the operational, technical and business requirements - identification may be achieved based on information from search engines, consulting firms, and from other sources. Selection of candidate platforms may be made between the traditional BI providers that have adapted their offer to the cloud or/and the new providers specialized in BI products in cloud.

The evaluation of solutions/providers has to be done based on the most recent sources (provider, consulting firms, the newest articles), the rest of the sources of information representing the grounds for obtaining a global image of the market of BI in CC. Within this stage takes place the analysis and testing of solutions, the selection of candidate solutions, identification of major changes and obtaining insurance from the selected providers. The model of decision for choosing the solution combines strategic factors and techniques with cost-benefit analyses for decisions of migration, versus integration or keeping in house (see Fig. 8).

Table 3. Restrictions BI technology on SME sector vs. CBI system conception
(*source: own research*)

Restrictions BI technology in SME sector	CBI solution
lack of knowledge in the area of possibilities effectively support management decisions	supplied as the complete solution and does not require knowledge of advanced information technology
limited knowledge of modern methods and models of business management	based its concept of architecture and structure of the data model on the predefined model of key competitiveness factors, dedicated to a specific group of enterprises
inability to self implementation and maintenance of BI system	implemented and delivered as a service (e.g. outsourcing, cloud computing)
limited resources for budgeting IT projects	implemented, maintained and funded as a product shared by a group of enterprises, and not as individual solution
limited and insufficient number of collected source data	supports a whole group of comparable and competing firms in the data collected and shared the results of analysis

The major decisions, in this model, are: strategic analyses for grounding decisions of migration/ integration/ keeping based on business factors, architectural analyses based on intangible cost-benefit analyses of strategic decisions and the selected solution based on the analyses made.

Based on the final offer of the provider, the team will measure the impact of the selected solution on the organization, assessing costs and benefits in order to determine the opportunity of integration and the key elements under negotiation. Finally, based on the offer and the model of contract, the contractual elements are negotiated: price, service conditions, payment, obligations of the parties, etc., and the contract is closed.

Implementation of solution may be achieved in iterative stages, through continuous transmission of data, services and processes toward the cloud, with possible returns from the cloud to operations hosted internally. This is achieved through continuous evaluations of the benefits of cloud technologies. Also, implementation involves setting a flexible program of risk management (to cope with IT risks that are increasing continually), testing the solution's performance and the management of implementation.

Utilization of solution involves changes in the manipulation of processes, such as data processing, development, receipt of information, means of storage, archiving and saving data, etc. Migration of critical applications and infrastructure to CC and maintaining the business activity involves important human resources for the management of sensitive data and of applications during migration. At the end of the solution's implementation takes place the training of users in operating the new systems.

At the level of the management stage must be present a management model that should include policies on security, the management of applications and infrastructure, risk management and continuous evaluation of solution. An efficient management is essential for any quality management program. It supports proactive ensuring of quality by measuring and improving processes, procedures and services. Besides the typical components of BI solution in monitoring solution must be taken into account the specific elements of CC environment. Among them, the most important are: monitoring URLs, monitoring system resources, monitoring log files, event management, multi-client capabilities, evaluation of contracts with providers.

The process of selecting strategy is iterative and is based on the results of the technical and economical analyses. Every iteration of the presented cycle identifies and eliminates the platforms of solutions that are unacceptable or unavailable, configurations that are too expensive or solutions with an unacceptable level of security. The number of iterations depends on the number of available candidate solutions. An attempt to select and propose concrete the solutions for a SMEs group will be shown in the next section.

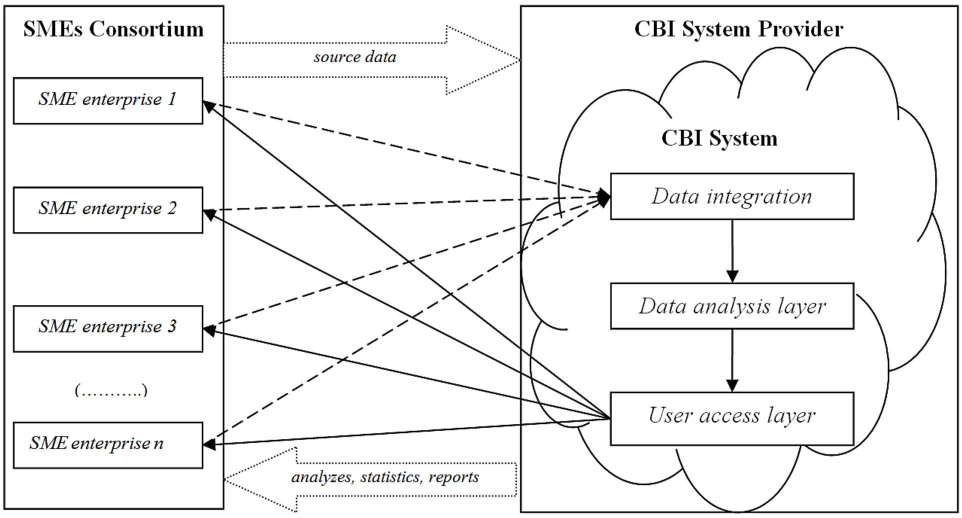

Figure 9. The model of CBI system for SMEs Consortium
(*source: own work*)

5 Cloud Business Intelligence for SMEs – proposition of using

Proposed concept of CBI is based on the assumption that SME receives ready to use product, which actively supports the development of its competitive strategy. This has a direct impact on the scope of the functionality of BI tool, but is necessary due to the low awareness of management employees and thus also to the lack of skills to use computer applications supporting the decision-making process. This problem does not only concern the SME sector, but all uses of advanced analytical systems which after implementation are not properly operated and consequently does not bring expected economic and performance outcomes. Proposed BI solution has predefined modules equipped with complete set of analyzes and reports (dedicated to specific industry or business) and data warehouse integrates data collected from group of enterprises (instead from single one).

With the adoption of a common solution for the group of comparable and mutually competing enterprises becomes available the functionality, which has hitherto was not known. It is a possibility of realization of a benchmarking analysis in the group of competing firms. Based on these analysis is possible to determine their competitive position and benefit from the experience of the group leaders during define the individual strategy for competitiveness. Specific reference to the restrictions in relation to the solutions proposed in system presents Table 3.

The model of CBI system is presented at Fig. 9.

The aim of CBI implementation is to support decision-making process in managing of competitiveness development. Use of CBI for this purpose will result in:

- the ability determine the current enterprise position of the competitive market,
- the adjustment of competitiveness development strategy to this competitiveness position which the enterprise intends to achieve in the future.

This is made possible by the fact that source data into the system are delivered by the group of users, and not by a single enterprise. This concept is consistent with the approach proposed by analysts of Gartner Institute [33], who at Gartner BI Summit Conference in May 2011 proposed the output with BI system outside the enterprise by using not only internal but also external data sources. The postulate was seen as useful, but very difficult to pursue. Proposed solution demonstrates how it can be achieve in the practice

Group of CBI users periodically delivers their source data over the lifetime of the system. It is a prerequisite to ensure its actuality and usefulness. The source data are integrated in a common repository of data, processed analytically and made available to users in the form of ready-made analytical results, statistical summaries and reports.

Data model (data integration layer at Fig. 9) and analytical layer of CBI system are dedicated exactly to the needs of its users.

They are based on the competitive model, selecting key competitiveness factors and designating the current competitive position of the enterprise in the group. In addition CBI system is delivered as a service, so the management of it is on the provider side and not the users. There are many different variants of outsourcing services in BI systems [2, s. 1164]:

- reporting service - outsourcing of tools to build analytical reports via the internet based solely on local data of the user,
- OLAP service - outsourcing of multi-dimensional analytic structure built on the basis of market data, which can be expanded on user's own data and integrated with its analytical system,
- data mining and visualization of data service – the client uses an external service of professionals in the implementation and the presentation of results analyzes based on the resources of own collected data,
- data warehouse and ETL service - supplying data into the data warehouse and maintaining its resources is done exclusively by the equipment provider.

It is clear, that these types of outsourcing services can be combined, for example by taking advantage of data warehouse and ETL service with data mining and data visualization service. The chosen variant of CBI system type will have then a direct impact on its architecture. Right choice the variant of CBI system implementation is determined by the answers to three basic questions:

- what elements of the CBI system the enterprise is able to maintain independently, and which must be transferred to outsource?
- what resources of data are available for analysis (in terms of their quantity, quality and range of information) and what is their level of confidentiality?
- how many the enterprise is able to pay for the implementation and the maintenance of CBI system?

The answer to these questions allows the selection of a package of services which must be done outside and those that can be implemented locally. It should carefully consider rights and responsibilities of the provider and the recipient in the range of organization and management of CBI architecture, taking into account the need to ensure a dynamic development of this architecture and available system functionalities. Adjustment of the project from one side to the needs and on the other side to the capacity of the enterprise is simply defining the set of system functionality in the case of using outsourcing or cloud computing services. That set of functionality ensures the implementation of user needs and is acceptable for the enterprise taking into account the extent of obligations arising from the need to ensure system efficiency and costs (taking into account amounts associated with maintenance of the system such as monthly fee).

In proposed concept the stage before the implementation of CBI system project is the construction of reference model of key competitiveness factors. Main goal of the model is determining the competitive position occupied by the enterprise in analyzed group. The model allows both: to conduct internal analysis of the competitiveness of the enterprise, and to compare its situation with respect to the competitive environment (which are co-users of CBI system). Obtained results provide managers with the knowledge about the importance and the impact of identified key competitiveness factors on the competitive position, which then is reflecting in developed strategy and results in increase the efficiency of competitiveness development management. Applying reference model of key competitiveness factors as the basis for CBI system project, guarantees its suitability and usability for the enterprise in defined range of analytical and decision-making uses.

Using CBI system always increases the awareness of managers in possibilities of using IT solutions in decision-making process. Analytical and reporting needs of users are changing and usually expanding during the work with the system. If the system is supplied as a service its development is possible and available at any time of user requests. Expected changes in services are provided by the supplier and only burden for the user is the change of monthly fee. Presented CBI system concept, offered as a service with predefined analytical module and database structure adapted to this module, becomes economically, technically and organizationally available for SMEs.

Measurable and immeasurable benefits of using that system are described in Tab. 4. The implementation and effective use of CBI system will result in time savings, rationalization of costs and the optimization of management efficiency. Proposed system architecture also allows the enrichment of own management experience by experiences of competing enterprises in the common market, according to good practices and ethical code of benchmarking.

Table 4. Expected effects of the implementation of CBI system dedicated to SMEs
(*source: own research*)

Feature of CBI system	Measurable effects	Immeasurable effects
analysis of competitive position of the enterprise	maximization of the profit, rationalization of costs	supporting of setting goals and directions of a development of competitive strategy
benchmarking results between co-users CBI system	maximization of the profit, rationalization of costs	determination of competitive strategy targeted by experiences co-users of CBI
analyzes and reports	budget preparation	reduction of uncertainty degree in management decision-making process
predictive analysis	rationalization costs incurred for the development of enterprise competitiveness	reduction of operational risk in management decisions making process
analytical data repository, data warehouse	reduce the time to access to management information	increased availability of analytical data for wider range of users in any place and any time
multidimensional data processing tools	reduce the time to prepare and modify queries and analysis	increased availability of analysis for wider range of users in any place and any time
visualization tools, presentation and distribution of information	reduce the time to prepare, modification and distribution of reports	increased availability of management information for wider range of users in any place and any time
ETL tools	increase data quality also in transactional systems	data standardization in the whole of the enterprise and of co-users CBI system

The verification of usefulness proposed solution was based on the research experiment, which involved 10 of initial group of 150 dental clinics (covered by survey research[5], [28]). Data collected from these clinics were used to build DBI system (Dedicated Business Intelligence). The purpose of using system was to determine competitive position of each clinic in the group. This was made possible by creating reference model of key competitiveness factors, which in three identified areas of measurable effects (E1 - modernity and quality of medical services, E2 - the ability to meet the needs of patients, E3 - results of sales) on the basis of calculated values of key competitiveness factors (C1- technological level, C2 – the quality of services, C3 - timeliness of service delivery, C4 - lasting relationships with customers, C5 - sales, C6 - costs and expenses, C7 - the utilization of fixed assets, C8 – the staff productivity) defined value of the competitive position CP for each enterprise in analyzed group. Then benchmarking of obtained results allowed for matching strategy of competitive development for this competitive position, which the clinic intends to take in this group in the future [28].

Results obtained during the experiment confirmed the usefulness of the proposed concept of DBI solution. DBI system enhanced by reference model of key competitiveness factors was more understandable, friendly and helpful to users than IT solution equipped only with analytical and reporting tools. As a proof of cost-effectiveness and effectiveness of DBI implementation it was carried out analysis, presenting below.

It is assumed that a properly implemented and effectively used BI system should be paid after 3 years of use. Accepting this argument and based on the results of research conducted by 180 Systems [6] and Pentaho [21] it can be concluded that the costs of implementation and maintenance of BI within the first three years of use are at a level of 30 000 - 100 000 $ in small companies and 30 000 - 400 000 $ in medium-sized companies. Referring to the cost of the financial performance of the SME sector in Poland can be said that the implementation of the BI system and keep it in the first year of life is a burden of 3.5% -25.5% of the annual earnings of a small company and 2.8% -30% average annual earnings the middle company.

During the 3 years, which is the assumed period of return on investment in BI, this load is 3,4% -12% 3-year earnings of a small company and 1% -13,5% 3-year earnings middle company.

[5] Scientific work financed from budget funds for science in 2009-2011 as a research project No. 0078/B/H03/2009/37.

Table 5. The participation of DBI system cost in financial results of the group of 12 small enterprises (summary about 25 users) (*source: own research*)

Software vendor	Solution name	System cost / financial result [%]	
		in 1st year of the system lifetime	within 3 years of the system lifetime
Microsoft	SQL Server 2008 R2 Enterprise Edition	0,86	0,29
QlikTech	QlikView	1,36	0,69
Pentaho (open source solution)	Pentaho Business Intelligence Gold Edition	0,86	0,86
SAP	SAP BusinessObjects Edge Professional Edition	4,54	2,05
MicroStrategy	MicroStrategy 9	6,28	2,85
IBM	Cognos 8 Business Intelligence	6,72	3,16
Oracle	Oracle Business Intelligence Suite Enterprise Edition Plus	9,17	4,16

Especially the upper limits of these ranges are a barrier for capabilities of implementing BI in SMEs By adopting the proposed DBI solution, in which users of the system is a group of 12 small enterprises SMEs and system architecture is planned for about 25 users, load in the first year of the system is less than 10% of the earnings of each company, and in 3-year period below 3,5% of 3-year earnings of each of them (see Table 5).

Thus, for each of the project implementation, knowing the estimated costs as defined by the software vendor and the service provider, you can determine the optimal size of the group users DBI system, which will reduce costs and increase the efficiency of its implementation.

Considering the effects of the use DBI solution in the research group it can be note the change of the results after using prepared analyzes and reports in 2008-2009 and their impact on the results of 2010 (see Table 6).

Table 6. DBI system efficiency in 2010 (*source: own research*)

The period of analysis		Number of patients	The gross of sales value	The profit value	Number of patient visits
2008-2009	on average within 2 months [thousand. PLN]	4714	319,00	28,00	2011
	on one patient visit [PLN]		158,64	13,73	
2010	on average within 2 months [thousand. PLN]	18742	603,00	97,00	3760
	on one patient visit [PLN]		160,28	25,68	
The difference: 2010-(2008/2009)	on average within 2 months [thousand. PLN]	14028	284,00	69,00	1749
	on one patient visit [PLN]		1,64	11,95	

Table 7. ROI for the implementation of DBI by a single vs. a group of 10 clinics
(*source: own research*)

Software vendor	Solution name	ROI (1year) for single clinic	ROI (1 year) for a group of 10 clinics	ROI (3 years) for single clinic	ROI (3 years) for a group of 10 clinics
Microsoft	SQL Server 2008 R2 Enterprise Edition	35,64%	1256,38%	306,91%	3969,13%
QlikTech	QlikView	-14,49%	755,11%	68,58%	1585,78%
Pentaho (open source solution)	Pentaho Business Intelligence Gold Edition	35,64%	1256,38%	35,64%	1256,38%
SAP	SAP BusinessObjects Edge Professional Edition	-74,46%	155,42%	-43,54%	464,62%
MicroStrategy	MicroStrategy 9	-81,53%	84,67%	-59,31%	306,91%
IBM	Cognos 8 Business Intelligence	-82,75%	72,52%	-63,24%	267,62%
Oracle	Oracle Business Intelligence Suite Enterprise Edition Plus	-87,35%	26,48%	-72,10%	178,97%

The 2-monthly periods of 2010 compared to the years 2008-2009 the gross sales value grew by an average of 284 thousand. PLN, and the value of profits earned in that period by 69 thousand. PLN. Assuming that about 50% of this profit is a result of the use of prepared analyzes and reports in the management process and that this trend will be permanent, it becomes possible to calculate the rate of return on investment ROI in one-year and three-year periods (see Table 7).

Table 7 shows that acting alone clinics could implement only the cheapest solutions - Microsoft, QlikTech or Pentaho. However as a group of 10 clinics, using a common system of DBI, are able to benefit from the offer of any vendor, even with the most expensive solution at the market. In this situation the determinant of used technology are not limited financial resources, but the actual analytical and information needs of an enterprise. This confirms the validity of the concept of group system implementation for the SME sector.

6 Summary

On the basis of researches results, shown in the paper, it can be stated that nowadays SMEs in Polish market have very small extent to use of IT tools to support managerial decision-making process. However, as practice shows and conducted BI market researches, use of IT tools can significantly increase the quality, and reduce the risk and costs of such decisions. As has been shown the Cloud Computing creates new opportunities for implementation of the Business Intelligence systems in these business sectors and organizations, for which up to now it was not feasible for many different reasons.

The implementation of typical BI solutions in the form of the system (as a whole realized and maintained by the enterprise) in most cases is for SMEs technically, organizationally and economically impossible. It is also very difficult for network and virtual organizations, consisting of multiple cooperating objects. Additional constraint is the low awareness of the managers in the SME sector in the scope of information technology and advanced methods of data analysis and insufficient number of collected data. Therefore, the proposed solution is based on following assumptions:

- CBI system is offered as a service for not only one but for whole group of SME users,
- all users of CBI supply their data into the system, thus increasing informational and analytical system strength,
- the construction of CBI system is based on predefined components, in which the key role plays the reference model of competitiveness factors, dedicated to specific group of SMEs,
- the use of CBI system is intuitive, focused on the use of ready-made packages of analysis and reports scenarios.

The proposed concept of CBI system can efficiently support the development of strategies shaping competitiveness in SMEs. Therefore, it is the prospect of develop BI technology and the possibility of its wider use in enterprises of all business sectors.

Moreover, this kind of solution is not only reserved for SMEs. It can be a great opportunity for both network and virtual organizations that nowadays are seen as flexible and cost efficient. Despite their structure and physical location (a virtual organization might not have even have a permanent office), they still require an intensive knowledge sharing and exchange. Unfortunately, in this environment, a traditional BI solution could be highly difficult to introduce. A BI system in CC technology opens new chances that may result in profits presented in the second section. As the technology is fast-moving those organizations benefit from the new possibilities on the market-place. Smirnov et al. [29] mention some of them in such a collaboration environment:

- decentralization: business services can be completely decentralized and distributed over the Internet and accessed by a wide variety of communications devices,
- dynamic interoperability: new business partnerships can be constructed dynamically and probably even automatically,
- flexibility: a highly-dynamic enterprise consortium have greater possibilities to use new market opportunities.

To sum up, BI system in CC technology opens up new perspectives for: SMEs, network and virtual organizations and many others, who need effective support when making management decisions, and are not in a position themselves implement and maintain BI system.

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