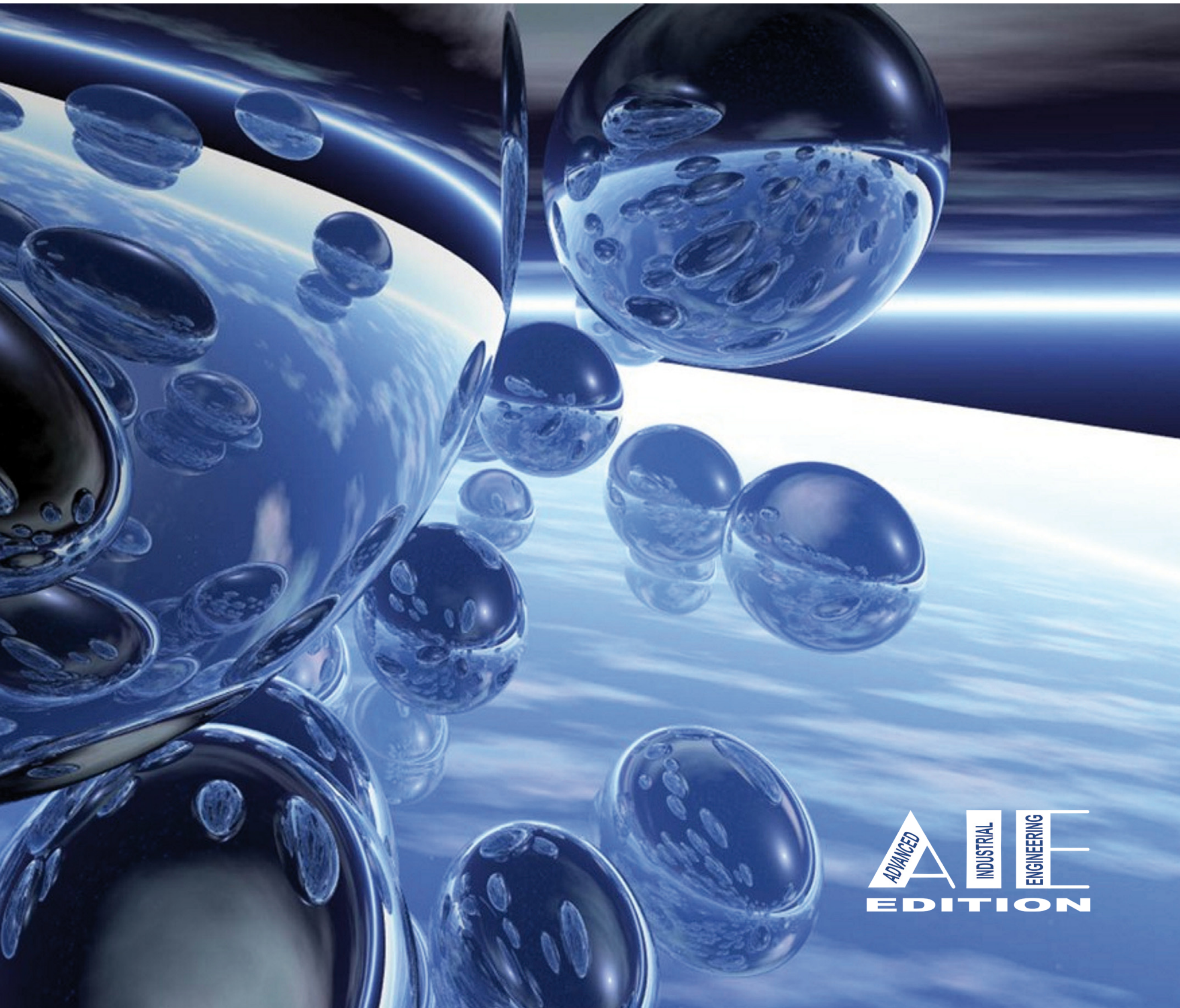
NEW ASPECTS OF MANUFACTURING ORGANIZATIONS' DEVELOPMENT

Branislav MIČIETA – Tadeusz WIECZOREK – Józef MATUSZEK



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NOVÉ ASPEKTY ROZVOJA VÝROBNÝCH ORGANIZÁCIÍ

Edited by:
prof. Ing. Branislav MIČIETA, PhD.
prof. dr hab. Tadeusz WIECZOREK
prof. dr hab. inż. Józef MATUSZEK

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prof. Ing. Branislav Mičieta, PhD.
prof. dr hab. Tadeusz Wieczorek,
prof. dr hab. inż. *Józef Matuszek*

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ORGANIZATIONS' DEVELOPMENT

Monograph

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prof. dr hab. inż. *Józef Matuszek*

NOVÉ ASPEKTY ROZVOJA
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Monografia

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Obsah

Introduction

Manufacturing organizations are the beating hearts of economical growth and therefore also the quality of life in every country. This holds true evermore today, with the continuing economical crisis and negative implications of the current economical system becoming apparent around the world. Turbulent and dynamic changes of the global environment are emerging, impacting operations of every enterprise. In addition, the market environment surrounding these enterprises can be well characterized as hyper-competitive. In such conditions, the companies are forced to utilize all their back-up resources, inherent potential of their employees, develop new technologies and intelligent solutions. Every new piece of knowledge can become helpful as a support for improving this situation.

The present work is an outcome of research carried out at three specialized departments specializing in the field of modern industrial engineering, lead by the editors of this volume: Department of Industrial engineering, University of Žilina, Department of Management and Computer Science, University of Silesia, Katowice; and Department of Industrial Engineering, University of Bielsko-Biała, Bielsko-Biala.

The monograph "New aspects of manufacturing organizations" is interdisciplinary and consists of two main parts. The first part seeks to address selected areas pertaining to manufacturing organizations. The second main section focuses on the system environment indispensable to efficiency of any manufacturing organization. Both sections present new pieces of knowledge developed by a wider team of authors in their original research, organized into nine thematic units (subchapters).

The introductory subchapter focuses on product lifecycle management and technology in manufacturing enterprises. The focus is specifically aimed at the examination of factors influencing this cycle and the emphasis placed on innovation activities pertaining to products and technologies enhancing the enterprises' market value. To support the claims a case study from the metallurgical industry is presented.

The next subchapter discusses the problem of flexibility of small businesses in supplying products to the market. It points to possibilities of utilizing information technologies to effectively manage large sets of product variants. The proposed approach is documented and its merits justified by another case study.

The third sub-chapter deals with ergonomics, placing the human being in the first place. It emphasizes the role of designers, who need to create the best possible conditions for people in the actual manufacturing process. Here, progressive approaches to designing workplaces are necessary, which require adoption of new tools and suitable methodologies.

Introduction

Possibilities of utilizing modeling and simulation techniques to successfully manage production processes are discussed in the fourth subsection. The case study included presents an analysis of a production system and its multi-criterial assessment in the furniture industry.

The first main part of the monograph is concluded with a subchapter dealing with managing and implementing innovations in industrial environments. This challenging set of problems is divided into three parts. Emphasis is placed on the fact, that no modern management systems can be developed omitting the theoretical basis and methodological tools supporting emergence of innovation.

The second main part of the monograph focused on the system environment sustaining the manufacturing organizations, begins with a subchapter on systemic solutions and problems in the area of occupational safety and hygiene in manufacturing plants in Poland. Particular attention is given to unfavorable work conditions and the role of clusters in the development of occupational safety and hygiene.

The following subchapter elaborates on the impact of corporate social responsibility. The theoretical part mainly discusses various rules applying to corporate social responsibility. Next, these findings are confronted with the actual realities in a case study from a steel mill environment.

The penultimate subchapter discusses clusters as possible sources for increasing performance of organizations. It highlights the potential emerging from enterprise networking and analyzes procedures that may be used to determine the effectiveness of such clusters.

The last subchapter looks at the issue of training of experts for field practice. It focuses on the methods of calculating costs related to preparation of skilled personnel at the universities.

The publication is published as trilingual. This follows well established communication practices of its Slovak and Polish authors. The editors wish to thank all the authors of various parts of the monograph, as well as their reviewers. They believe that the findings published herein will serve a wide spectrum of readers.

prof. Ing. Branislav MIČIETA, PhD.
Head of Department of Industrial engineering, Žilina

prof. dr hab. Tadeusz WIECZOREK
Head of Department of Management and Computer Science, Katowice

prof. dr hab. inż. Józef MATUSZEK
Head of Department of Production Engineering, Bielsko – Biała

Predhovor

Výrobné organizácie sú motorom hospodárskeho rozvoja a následne i kvality života v každej krajine. O to viac v súčasnosti, keď vo svete pretrváva hospodárska kríza a prejavujú sa negatívne dôsledky svetového ekonomického systému. Do popredia vystupujú turbulentné a dynamické zmeny globálneho prostredia, ktoré vplývajú na činnosť každého podniku. Samotné okolie podnikov možno charakterizovať ako hyperkonkurenčné trhové prostredie. V tejto situácii sú podniky nútené siahať na všetky svoje rezervy, využívať vnútorný potenciál svojich pracovníkov, rozvíjať nové technológie a inteligentné riešenia. Každý nový poznatok môže podporiť zlepšenie tejto situácie.

Predkladaná publikácia je výsledkom výskumu pracovníkov na troch špecializovaných katedrách zameraných na oblasť novodobého priemyselného inžinierstva, ktoré sú vedené editormi tejto publikácie. Jedná sa o nasledovné pracoviská: Katedra priemyselného inžinierstva na Žilinskej univerzite v Žiline; Katedra Zarządzania i Informatyki, Politechnika Śląska Katowice; a Katedra Inżynierii Produkcji, Akademia Techniczno-Humanistyczna, Bielsko-Biała.

Monografia „Nové aspekty rozvoja výrobných organizácií" má interdisciplinárny charakter. Pozostáva z dvoch hlavných častí. Prvá časť je zameraná na riešenie vybraných oblastí vo výrobných organizáciách. Druhá hlavná časť sa sústreďuje na systémové okolie, bez ktorého výrobné organizácie nemôžu efektívne pracovať. V oboch častiach sú prezentované nové poznatky širšieho kolektívu autorov, ktoré boli získané vlastným výskumom. Poznatky sú sústredené do deviatich tematických celkov (podkapitol).

Úvodný tematický celok je zameraný na problematiku riadenia životného cyklu výrobku a technológie vo výrobných podnikoch. Špecifikom je skúmanie vplyvov na tento cyklus. Dôraz je kladený na inovačné aktivity podnikov v oblasti výrobkov a používaných technológií, ktoré zvyšujú trhovú hodnotu podnikov. Na podporu daného tvrdenia je použitý príklad z metalurgického odvetvia.

Nasledujúca podkapitola je príspevkom k riešeniu problematiky pružnosti dodávok produktov malých spoločností na trh. Poukazuje na možnosti využitia informačných technológií pre efektívnu správu veľkého množstva variantov produktov. Opodstatnenosť daného prístupu je dokumentovaná na prípadovej štúdii.

Tretia podkapitola je venovaná ergonómii, kde na prvom mieste je človek. Zdôrazňuje úlohu projektantov, ktorí musia vytvárať pre ľudí čo najlepšie podmienky vo výrobnom procese. K tomu je potrebné využívať progresívne prístupy k projektovaniu pracovísk, ktoré vyžadujú akceptovanie nových nástrojov a vhodných metodických postupov.

Predhovor

Možnosťami využitia techník modelovania a simulácie pri riadení výrobných procesov sa zaoberá štvrtá podkapitola. Je tu realizovaná analýza výrobného systému a jeho multikriteriálne hodnotenie na príklade nábytkárskeho priemyslu.

Prvú hlavnú časť monografie uzatvára podkapitola venovaná procesom riadenia vzniku a implementácie inovácií v priemyselnom prostredí. Táto náročná problematika je rozdelená do troch častí. Kladený je dôraz na skutočnosť, že nemožno budovať novodobé systémy riadenia bez využívania teoretických základov a metodických nástrojov podporujúcich vznik inovácii.

Druhá hlavná časť monografie zameraná na systémové okolie podporujúce výrobné organizácie, začína podkapitolou venovanou systémovému riešeniu a súvisiacimi problémami týkajúcimi sa bezpečnosti a hygieny práce v priemyselných podnikoch v Poľsku. Osobitná pozornosť je tu venovaná nevhodným podmienkam práce a úlohe klastrov pri rozvoji bezpečnosti a hygieny práce.

Nasledovná podkapitola rozpracováva vplyv spoločenskej zodpovednosti podnikov. V teoretickej časti sú rozpracované hlavne pravidlá o sociálnej zodpovednosti podnikov. Následne sú tieto poznatky konfrontované so skutočnosťou v prípadovej štúdii z prostredia oceliarne.

Predposledná podkapitola rozpracováva možnosti klastra, ako jedného z potenciálov zvyšovania výkonnosti organizácie. Poukazuje na pozitíva, ktoré v sebe skrýva sieťovanie podnikov a rieši postup zisťovania efektívnosti klastra.

Posledná podkapitola je zameraná na oblasť prípravy odborníkov pre prax. Sústreďuje sa na výpočet nákladov, ktoré sú zviazané s prípravou kvalifikovaných pracovníkov na vysokých školách.

Publikácia je písaná ako trojjazyčná. Nadväzuje to na zaužívané komunikačné praktiky slovensko–poľských autorov podieľajúcich sa na jej príprave. Editori ďakujú všetkým autorom jednotlivých častí monografie a recenzentom tohto diela. Veria, že publikované poznatky uvedené v monografii poslúžia širokému spektru čitateľov.

prof. Ing. Branislav MIČIETA, PhD.
vedúci Katedry priemyselného inžinierstva, Žilina

prof. dr hab. Tadeusz WIECZOREK
kierownik Katedry Zarządzania i Informatyki, Katowice

prof. dr hab. inż. Józef MATUSZEK
kierownik Katedry Inżynierii Produkcji, Bielsko-Biala

1

SOLUTIONS FOR SELECTED AREAS IN MANUFACTURING ORGANIZATIONS

RIEŠENIE VYBRANÝCH OBLASTÍ VO VÝROBNÝCH ORGANIZÁCIACH

Chapter 1.1.

MODEL MANAGEMENT OF PRODUCT LIFE CYCLES AND TECHNOLOGY LIFE CYCLES IN MANUFACTURING ENTERPRISE TAKING INTO CONSIDERATION PERIODS OF SECTOR AND COMPANY LIFE CYCLE

MODEL RIADENIA ŽIVOTNÉHO CYKLU VÝROBKU A ŽIVOTNÉHO CYKLU TECHNOLÓGIÍ VO VÝROBNÝCH PODNIKOCH SO ZRETEĽOM NA CYKLUS V SEKTORE A ŽIVOTNÝ CYKLUS PODNIKU

Bożena GAJDZIK[1], Andrzej WYCIŚLIK[2], Tadeusz WIECZOREK[3]

Key words: sector life cycle, company life cycle, product life cycle, technology life cycle

Abstract
In this publication the issues of product life cycle and technology life cycle in a manufacturing enterprise are presented, including the dependences occurring between management of product life cycle and the application of the best technological solutions available. A model has been developed, which is based on the innovative activity of the enterprises in reference to products and devices. Their modernisation allows for maximising the market value of enterprises. Moreover the development of product and technology is connected with sector and company life cycle. For example metallurgical branch particular periods were presented. Authors considered two models of economy for metallurgical sector life. First model was central planed economy, second – market economy. Changes in particular periods of the sector life were presented.

[1]D.Sc. Eng, Silesian University of Technology, Department of Management and Computer Science, 40-019 Katowice, street. Krasińskiego 8, Poland.
[2] D. Sc. Eng. Ph. of Silesian University of Technology, Department of Management and Computer Science, 40-019 Katowice, street. Krasińskiego 8, Poland.
[3] Ph. D. Sc., Silesian University of Technology, Department of Management and Computer Science, 40-019 Katowice, street. Krasińskiego 8, Poland.

1. Assumptions the development of management of product life cycle and technology life cycle

In recent years the value of innovations management of all the functions occurring in enterprises is underlined. The essence of this matter is introduction of novelties into business practice. The actions which are considered innovations are the introductions of new products or new technologies, finding new sources of resources and new organisation of enterprise functioning (1).

On the assumption, that:

- new or modified product is a key element of innovation and the source of predominance in enterprise competition in present market economy,
- the (basic) productive processes and service processes (auxiliary) of enterprises are based on technologies, and the level of their modernisation decides on the quality of the products and the influence of the enterprise on the environment,
- innovation is the basic factor in construction of the market value of the enterprise, it was presumed, that nowadays the management of the product life cycle allows enterprises for fluent implementation of a new technology in the best possible moment of their market strategy realisation. It was also assumed that there is dependence between the product life cycle and technology life cycle. The management of cycles is an interactive process, in which the enterprises interact with clients of products, the suppliers of modern technologies and service companies or other entities in the surrounding.

It was stated, on the basis of literature analysis, that classic product life cycles and technology life cycles go through the following stages: introduction, growth, maturity and withdrawal from the market. Each phase has other implications for the final user. The recipients of final products assess their usefulness by their usability. The producers prepare a detailed analysis of the income from product sales in each phase of the cycle.

In the economy based on enterprise knowledge, in order to develop systematically and in a stable way, the enterprises must learn how to broaden the scale and range of business activity by introduction of new products and technologies faster than competition. Enterprises should base their strategy on development of modern products and new or modernised technological solutions. In developed countries the customers expect products with highly innovative qualities. The confrontation of the customer expectations with the enterprise possibilities allows for identification of strong and weak points in the interactive model of innovations.

The authors of the interactive model of innovation are R. Rothwellem and W. Zegveldem (fig. 1). Process of product innovation is a sequence of particular actions, which take place in the following areas (2): research and development (R&D), production and marketing.

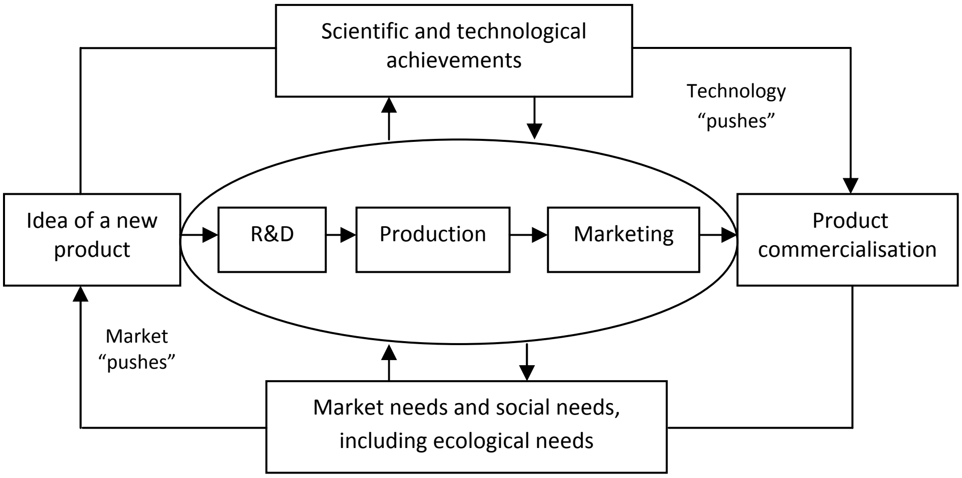

Fig. 1.: Interactive innovation model (2)

Interactive innovation model shows the connections between the introduction of innovative changes in products and changes in manufacturing technologies and the needs and expectations of the customers. The impulses for product modification or introduction of new products are the technological changes and new customer needs.

It may be derived from the presented assumptions that it is necessary to connect the life cycle of a product with life cycle of a technology. The authors of this publication agree on the fact how vital is the integrated analysis of the management of each phase of product life cycle and technology life cycle in the enterprise management as a whole, and in particular in management of product innovation. The aim of the authors of this publication is to design a model of product life cycle and technology life cycle management in the aspect of innovativeness for manufacturing enterprises.

2. Phases of product life cycle and their connection with technology life cycle

Life cycle of a product is in a nutshell the whole history of its manufacturing and application. It begins from natural resources and other production materials, lasts during all stages of manufacturing and application of the product and finishes in the form, in which the product or its elements come back to manufacturing processes (internal or external recycling). Such system of product life cycle may be presented in a form of a dependence loop: environment – consumption- environment. This cycle is referred to as LCA (Life Cycle Assessment). It allows for a comparison and assessment of inputs and outputs of a manufacturing system and its potential influence on the environment in the full cycle of existence (3).A simplified cycle structure is presented in fig. 2.

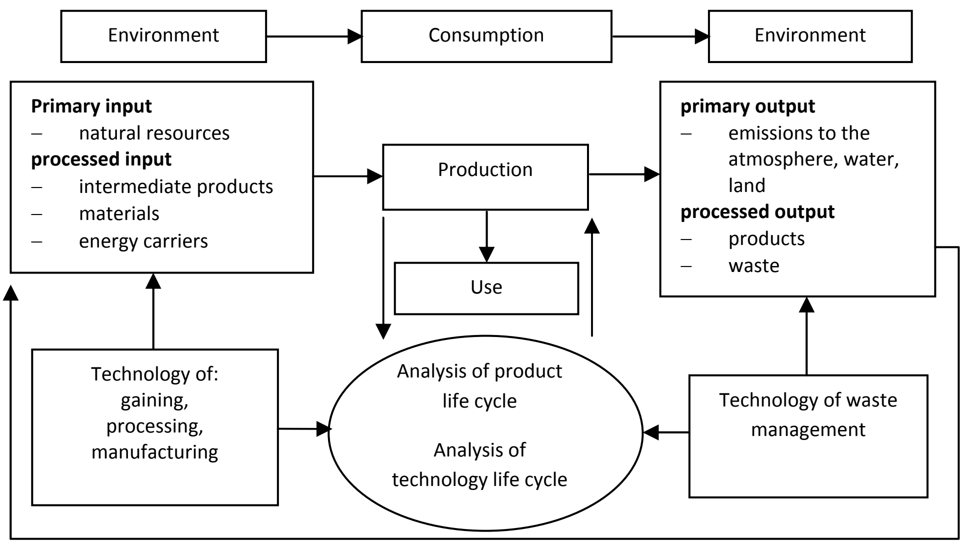

Fig. 2.: Flow diagram of input and output of product system (own study)

“Product life cycle shows the phenomenon of product gradual getting and losing the ability of satisfying the needs of a customer, as well as the process of increasing the cost connected with product innovations, their elaboration, introduction on the market and maintenance of their presence on the market” (4).

In the model: environment – consumption – environment a multi-level use of all the waste is assumed, which as a result gives zero waste and zero emission. Some products influence the environment to a highest degree during the production and some during use or utilisation. Before a product is put on the market rigorous tests are conducted concerning its influence on the environment in the whole time of use. The total analysis starts from the moment of output of resources and accompanies the environmental aspects of production, distribution (including packaging), use and utilisation of the product. Of course, for various products the biggest influence on the environment occurs in different stages of their life cycle. For example, the metallurgical products significantly influence the environment mainly in the process of production (metallurgical slag and open-hearth slag, gas emissions into the air, mainly of carbon dioxide). That is why the decrease of negative effect on the environment is mainly focused on the decrease of harmful effect of those processes, which influence the environment to a greatest extent (3).

Main factors which are taken into account in the assessment of product and technology influence on the environment are:

- availability and renewability of the resources in nature,
- pollution emission during gaining, processing and creation of products,
- use of energy, water and other media in the manufacturing process.

In table 1 the environmental aspects are presented in full ecological product life cycle, taking into account two types of technology, which are the old-fashioned one (decline phase of technology life cycle) and the modern one (fully active phase of the technology).

In the analysis of the market life cycle of a product (classic model, so-called marketing model) there are four main phases (4, 5):

I. introduction (the product is put on the market),
II. growth (the number of buyers of the product increases, income from the sales),
III. maturity (the enterprise reaches optimum income from the sales of the product, the market is glutted with the product),
IV. decline (sales drops and the product disappears from the market).

Table 1.

Ecological aspects product life cycle and technology life cycle analyses (own study)

Phases of ecological life cycle of a product	Type of technology	
	Old-fashioned technology	**Modern technology**
Output of resources, access to materials and intermediate products	o limited access to resources, intermediate products, materials o natural resources dominate (primary)	o easier access to resources, intermediate products and materials o artificial resources dominate (processed)
Manufacturing of products	o high level of pollution emission to atmosphere, water, land, o static model of environment protection (second waste management)	o low level of pollution emission to atmosphere, water, land, o low use of resources o dynamic model of environment protection (based on minimising procedure and prevention of waste formation)
Consumption of energy and other Media	o high consumption of energy, water and other reserves (high level of energy-consumption and material-consumption of the applied product manufacturing technology)	o low consumption of energy, water and other reserves (designing the product in reference to energy efficiency and aware consumption by the client may minimise the negative influence).
Consumption after use – of side-products	o small recycling and reuse possibilities of side-products use	o big recycling and reuse possibilities (the product can be easily fixed or recycled).

First phase is a period of high costs and low sales of products. Such situation causes losses or small profit for the enterprise. The risk of new product introduction on the market is a big risk, because the product is unknown to the customer (creation of needs). It is necessary to invest a lot in product marketing (elaborated promotional campaign) (4, 5).

In the second phase the dynamics of the sales is big and of progressive type. The company has big expenses on the production (preparation for mass production). The number of customers increase and distribution cost rises. Risk is still high, first competitors appear (4, 5).

Signals that the market is glutted with a product appear in the third phase. Dynamics of sales growth has decreasing character, the enterprise profit also decreases. The sales reaches maximum, market stabilises. Producers lower the price of the product in order to gain additional customers (4, 5).

In the last phase (fourth) the sale drops. Cost of unit manufacturing increases, as a result the profit drops and even a loss may appear. Executives in the enterprise begin actions connected with withdrawal of the product from the market or its modification (4, 5).

The length of product life cycle is different for various products and may last from a few to a several dozen of years. With the development of the post-industrial society the life cycles of products are gradually becoming shorter. Each enterprise does their best to lengthen the product life cycle because it causes lower cost of its development and better profitability.

Marketing specialists agree that each phase of product life cycle is characterised by different speed of demand change, different number of segments of product buyers, different number of competitors and different profitability. In each phase of product life cycle the elements of marketing actions are applied (mix marketing instruments), therefore the product characteristics, its sales price, expenses on communication of the enterprise with the surrounding as well as distribution channels. Details concerning marketing influence of the enterprise on the course of particular phases of product life cycle are presented in table 2.

Table 2.
Elements of marketing actions in each phase of product life cycle (5)

Specification	Introduction	Growth	Maturity	Decline
Demand	Growing	Rapidly growing	Stable	Decreasing
Segments	Few	A lot	A lot	Few
Competitors	Few	A lot	Some	Few
Profitability	Minus	High	High-low	Low
Product	New	Better quality	Rationalisation	No change
Price	From high to lower	From lower to higher	Stabilisation	Discount
Communication	Intensive	Intensive	Intensive	Weakening
Distributors	Few	A lot	A lot	Few

The choice of tools for the product life cycle management is subjected to, among other factors, the technological situation of the enterprise. Technology life cycle analysis is a tool used to test the competitive abilities of an enterprise in terms of technology. From the point of view of market value there are four types of technologies (4):

I. Experimental technologies (new), with a small range of application, but promising that in the future they will become key technologies; also very well protected against the competition.
II. Key technologies (developing) which are the basis of competitiveness of the products, their mastering is a key to success, they are highly protected.
III. Basic technologies (mature) widely applied in the sector, available and of small or weakening competitive value
IV. Decline technologies (outdated) – gradually withdrawn from the enterprises due to their economic and technical unprofitable aspects.

Technology life cycle runs similarly to product life cycle. The company bears the highest cost in the initial phases of the cycle and the biggest effects are generated by the technology in the maturity phase. The knowledge of the course of technology life cycle of a given company allows to prevent the formulation of a technological gap and protects the company against overinvestment in new technologies without making the most of technological possibilities used so far. In table 3 the types of products and technologies were presented together, taking into consideration all the phases of the life cycle.

Table 3.

Types of products and technologies in each of the phases of their life cycle (on the base of analyse BCG)

Life cycle phase	Introduction	Growth	Maturity	Decline
Type of technology (according to market value of a technology)	New (experimental)	Key (developing)	Basic (mature)	Declining (old-fashioned)
Types of products (marked according to BCG matrix)	New (problem children)	Developing (stars)	Mature (cash cows)	Old (dogs)

Market life cycle of a product also forms a closed loop if we analyse it in connection to management systems of the enterprise. The cycle begins from the consumer through producer to consumer again (*consumer – producer - consumer cycle*), as shown in fig. 3.

The model, presented above, is just an overall description of product life cycle concept in connection with functioning of internal systems in a manufacturing enterprise; its application requires suitable, detailed data and economical and technological studies. The enterprises should, depending on their production profile, conduct product life cycle analyses in reference to the internal and external factors. Such studies are helpful in the design and planning process of replacement of the existing products and technological solutions with new ones. Additionally the range of the analysis should be broadened by financial area, in order to assess the cost of development and introduction of an innovation. The following stages should be mentioned in the presented model of product life cycle:

I. Idea and concept formulation (thinking up),
II. Designing a new product (project and planning system),
III. Realisation (manufacturing of a new product based on new or modernised technology),
IV. Re-use (internal and external recycling).

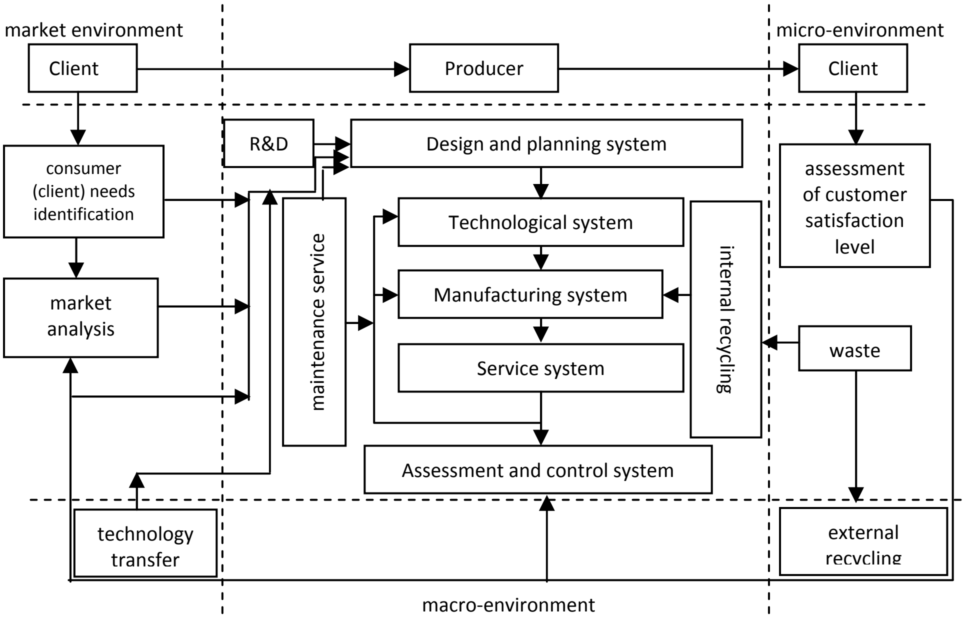

Fig. 3.: Graphic illustration of the cycle and systems in manufacturing enterprise (own study)

Formulation of the concept of a new product (thinking up) requires a deep analysis of the customer needs and market situation. Therefore, the first stage begins from customers, on the basis of their knowledge, by formulation of their needs, preferences, likes and the end of product's life occurs in case of the user when product is fully exploited and after re-use after real consumption. During the planning stage a directed scientific research is necessary. Enterprises may use the intellectual potential of their own workers employed in units dealing with research and development (R&D) or buy ready-made solutions – know-how (licences and patents)(6). A stage of detailed designing of a product occurs together with designing technological modernisations (purchase of new machines, devices, additional service back-up). Manufacturing of the products is more and more automated (*high technology*) and that is why in the analysis the IT computer systems existing in an enterprise are presented together with conceivable possibilities of purchase of new solutions. Technology transfer in innovative economy is realised according to the assumptions of open innovation model (*open innovation*) (7).

The characteristics of the open model is based on the exchange of the knowledge and experience between the enterprise and the environment, as well as the participation of the external organisations in the R&D works which is bigger than the amount of work performed internally within an enterprise. Time pressure and the cost of research and development works cause that the enterprises decide to use services of highly specialised units. In the "open" model the supply on the market with the broadly understood services connected with research and development, services connected with service of technology, counselling computer and design rises steadily. The key factor of development of the "open" model is globalisation of the markets of products and technologies. Global competition forces the enterprises to introduce quick changes, which favour being open to co-operation with the surrounding in terms of gaining innovations. The following factors also influence the development of the open innovation model: (7)

- easier access to knowledge and information exchange connected with Internet development,
- development and accessibility of innovations in many countries,
- appearance of new organisations dealing with R&D,
- growing competition on the market of manufacturing enterprises,
- new needs (requirements) of the customers,
- development of new outlets, including the developing countries and regions,
- global problems of environment protection and limited access to natural resources.

The most important stage of product management is the realisation of the designed innovations. This stage requires an efficient service back-up (maintenance service) and other back-up systems.

In the second stage there is a need of co-operation of three systems, which are technology – set of devices and machines needed for production; production capability – for creation of innovative products and service system; and maintenance – necessary for the proper course of production process and reliability of the applied technologies.

Manufacturing system is based on the analysis of product life cycle, whereas technological and service system on the analysis of technology life cycle. Particular life cycles have different characteristic features in each phase, the duration of them is different but their simultaneous analysis enables to determine the mutual influences between them. Such approach allows to test the market age of each product of a given enterprise and each technology used in it. The result of such analysis is the rational planning of the range of production and the costs connected with the introduction and creation of new products and technologies. In table 4 the dependencies between three systems of a manufacturing enterprise are presented - technological, manufacturing and service, including the phases of the life cycle.

Table 4.

Phases of product life cycle and technology life cycle in the systems of an enterprise (own study)

Phase of life cycle	Introduction	Growth	Maturity	Decline
Production system	production in small amounts	increase of the production size, a mass production begins	continuation of mass production, first production limitations appear	limitation of the production size, reduction of the assortment
Technological system	purchase of new technology, modernisation of machines and devices	preparation of technology to its full load	full exploitation of technology, first technical limitations appear	not full technology use, ageing of technology
Service system	service actions allowing for a quick start and technical back-up of new technology (installation and start, practical and theoretical training)	service preparing the technology to maximum load (choice of devices and their dimensioning, service of replaceable parts)	mending and repairing service, complex maintenance services	limited access to repair services and to replaceable parts

After long period of exploitation the technology goes into outdated phase. On the basis of such technology the enterprise is not able to produce modern products. The decline phase affects also the market products. A product is withdrawn from use and a phase of its re-use of the whole product or a part of it follows. In life cycle management this phase is significant and includes the issues of eco designing, environmental balance and striving at the zero waste production.

A life cycle of a product and technology is a technique of strategic analysis, enabling the application of the portfolio methods, the analysis of key factors of success, the test of money flow as well as strong and weak sides of the enterprise. On the basis of enterprise assessment results a decision is made to introduce product and technology innovations. The process of novelty introduction may encounter obstacles such as:

- high cost of product development and obtaining technology or purchase of licence,
- difficulties in access to the sources of resources,
- lack of permissions to sell certain products,
- lack of suitable experience in production or sales,
- difficulties in access to loans on preferential terms,
- complicated procedures of obtaining additional financial aids for innovations,
- legal limitations and lack of tax relief for innovative enterprises,
- low diversification level of sources of gaining and financing innovations,
- possible reputation loss, which may occur if sales of one product in a given enterprise was stopped,
- cost of damage of technological synergy existing between the products.

3. Phases of a company’s life cycle and their correlation to sector´s life cycle

Further and being under analysis are such cycles: company’s life cycle and sector’s life cycle (trade). In this thesis there was a test of analysing the interactions taking place between particular phases of these cycles. As a case study a steelworks sector in Poland was taken under consideration and other companies that operate within it.

In bibliography of a company's life cycle management the sequence of stages is presented which apply to each company throughout its existence on the market. These phases present particular differences both of a quantity character (the amount of profit gained form products sale, the level of capital invested, number of employees etc.) and a quality character (company's brand recognition). They are stimulated by various interior impacts (availability and structure of human resources, finance, products and information technology) and exterior of micro scale (market conditions) and macro scale (further surrounding for company's existence) (8,9).

In a company's life cycle there are various stages (9,10):

- Birth (launch, entering the market) – main aim of a company after entering the market is to realise the survival strategy in order to maintain on the particular market; the structure of organisation is simple because the company hasn't got extended administration and management department; in a business strategy it aims into immediate opportunities spotting,
- youth (growth/development) – this stage is characterised by the company's development, if the company catches arising opportunities and successfully and smoothly realises its strategy it quickly gains significant position on the market and as a result raising income from sale and profit'
- maturity – at this stage stabilisation of turnovers is observed, the company's position on the market is already worked out and is profitable in long term; it possess surplus of capital which is dedicated to further development; in this phase the companies have relatively low costs of running business thanks to scale economics,
- decline – companies appear to be in the crisis which endangers their further existence because of accumulation of many negative impacts (e.g. loss of profits, higher debts); the reasons of crisis may be external (e.g. drop of demand on particular products) and internal (mistakes in management); to prevent this phase of a company's life cycle at the stage of maturity the companies should undertake repair and preventative activities. Details concerned particular phases of a company's life cycle have been presented in the tab. 5.

Table 5.

Features of a classic company's life cycle (11)

Phase	Features
Birth	It is the time when a company enters the market. The phase of growth is characterised by low or none cash flow, rapid growth and delays in production. The company should start with the market penetration, firstly creating a clients' database lately a production strategy. With the moment of settling the business the company has permanent costs such as rent, salaries, insurance. These dues the company must pay apart from the scale of sale. At this stage a company is in need of large exterior sources – bank credit. In a business strategy a company aims into using opportunities that are created by the market and its surrounding.
Growth	A company in the phase of growth notes rapid income growth accompanied by raising number of clients. If the company feels the market gap other companies clients become its clients as well as these who have already become conscious of a new product or service. The clients database will grow unless it fulfils market's needs (it is to gather all possible clients), then the company passes to the phase of maturity.
Maturity	In this phase the company has already got a worked out market position and is able to forecast better its income and costs. The phase of maturity is characterised by stable growth in income (probably 5-10% annually) and high cash flow. Mature companies guarantee their shareholders permanent profit. The companies remain In the chase of maturity as long as they don't note the drop which may result from the drop in demand or other changes that take place outside the company.
Decline	The company slows down the growth speed, income begins to drop and again the company faces troubles with cash flow. The customers tastes start changing or a new technology is invented so the demand goes to new, substitute products. Companies with a long term thinking may, at least for short time, postpone the danger of decline by flexibility towards changes and offering new products or services. Nevertheless, at some point new competitive companies will be settled which take over part of clients. If the company doesn't possess strategic plans or overtake strategic actions it may be unaware of already being in the phase of decline. Such company may remain at this stage ever for many years (at least for as long as it has financial sources) and inquire why income is falling and cash flow in danger. In the phase of decline the company may approach a radical repair reconstructing or searching for the strategic investor because they are aware of having resources which can appear attractive to new companies. However other companies decide to broaden their activities and find new investment paths.

Table 6.

Phases of a classic sector's life cycle (4).

Phase	Features
Launching (birth)	o uncertainty and risk of doing business; o high information needs about the sector in particular forecast analysis (experts knowledge), o main meaning of technology and innovation; o limited competition; o high and changeable prices; o unprofitable business; o negative cash flow; o high capital needs to finance business; o searching for co-operation in order to lower costs of sector function.
Development (youth)	o fast growing demand; o fast growth of profitability (lowering of unit costs and maintaining of high prices); o entering the market by new companies; o growth of competition; o sudden drop of prices; o business becomes more profitable but still negative cash flow; o still high capital needs, o tightening of co-operation, o preparing mutual business strategies.
Maturity	o subsiding growth of clients' demand; o harsh competitive battle (also international competition); o high importance of advertisement and other marketing activities, o reducing the products prices, o drop in production and sale's profitability; o release of growth of productive capacity; o clients demand new products; o need of improving technology; o designing the new products, o capital aimed into reinvestment; o release of income, o searching the financial sources for innovation, repair, pro-development etc.
Decline	o market stagnation; o sale at the level to guarantee survival of particular companies in a sector; o leaving the sector by the companies that do not possess a strategy o repair and investing capital, o maintaining of a few companies operate within the market until there is no surplus and service companies; o drop in competition; o sale of companies' wealth; o low income, minimal cash flow, rather negative.

Some similarities may be found between company's life cycle and sector's life cycle (trade) where the companies function. In the sector's life cycle there are also phases of launch, development, maturity and decline. The model of sector's life cycle reflects the life cycle of companies, products and technology (copying these phases on the sector) because the stages correlate to already analysed development stages. The characteristic feature of a sector's life cycle (trade) is longer lasting period compared to already mentioned cycles. The phases of a classic sector's life cycle have been presented in table 6.

Basing on scientific experience of the authors and researches made by the article's co-author (12) the steelworks sector life cycle has been defined as well as the analysis of the life cycle of the biggest steelworks company in Poland, it is ArcelorMittal Poland SA.

In favour of analysis the sector's life cycle was divided into two key stages of development:

- stage I this is a period of centralised economy,
- stage II this is a period of market economy.
- during analysing of central planning period in Polish economy such phases of steelworks sector's life cycle were defined:
- birth of steelworks sector – phase in 40s/50s of 20th century,
- youth of steelworks sector – 50s/60s of 20th century;
- maturity of steelworks sector – 60s/70s of last century and partly 80s of last century,
- ecline of steelworks sector of centralised economy – 80s/90s of 20th century, the phase began with introducing market economy rules, the breakthrough took place in 1989 – the change of economic system (table 7).

After the decline phase accompanied by realisation of the new government programme of reconstruction of Polish steelworks of iron and steel (1992), some of the steelworks companies managed to enter the market once again. It was the starting point of another life cycle of companies and another life cycle of the sector after implementing repair-reconstructive programmes in particular companies. In chart.3. the phases of life cycle of polish steelworks sector were presented by the year of 1992, up to implementing by government the repair programme for steelworks sector.

Table 7.

The life cycle of steelworks sector in Poland in period from 1940 to 1992 (self study on base of 12, p. 34-35).

Phase	Period	Characteristic features
Launching (birth)	40s/50s of 20th century	1. Creating of steelworks companies mainly for interior economy needs. 2. New companied are created by direct investments or by taking over private companies by Polish government 3. Example steelworks companies that are settled in this phase: o 1936 Florian Steelworks, o 1949 – Cedler Steelworks, o 1954 – Lenin Steelworks. 4. In 1950 steelworks in Poland produce 2,5 millions of tons of steel.
Development (growth)	years 50/60 of the 20th century	1. More steelworks are set e.g. Huta Katowice – year 1976 2. Public enterprises are a dominant legal form 3. Big investment expenditures from government side on development of new enterprises 4. Expansion politics on employment (creation of employee estates in aim to satisfy personnel needs) 5. Systematic increase in steel production and metallurgical products, in 1960 – 6,7 mln tons of steel were produced 6. Gradual increase of the importance of steel export and metallurgical products
Maturity	years 60/70 of the 20th century and first years after the 1980.	1. Systematic increase in steel production, in 1970 – 11.8 mln tons of steel were produced 2. In the year 1980 Polish metallurgy reached the highest level in steel production which was 19.5 mln tons. 3. After the year 1980 steel production was gradually dropping and in 1990 was 13.6 mln tons. 4. Together with a production decrease of steel and metallurgical products appeared financial problems, steelworks reported a need for financial support from national budget financial resources, 5. Decrease in production was not accompanied by employment reduction thus steelworks did no reported a drop in employees performance (quantity of produced steel calculated for one employee) 6. Increase of employee dissatisfaction about the government's politics in relation to metallurgical enterprises
Decline	years 80/90 of the 20th Century.	1. Financial, personnel, technological, problems of steelworks. 2. Search for crisis solutions (sector restructuring programme) 3. Systematic drop in production of metallurgical products – yearly average of steel production on the level of 10 mln tons.

Table 8.
Periods of restructuring of metallurgical sector (works and steel) in Poland (12)

Phase	Period	Characteristics of restructuring changes
Introduction of restructuring principles into the metallurgical sector (birth)	Period I (1992-1995)	Time of formulation and acceptance by a Polish government of the primary restructuring and repair programmes (Canadian stadium). Establishment of rules related to sector restructuring.
Increase of importance of sector restructuring principles (youth)	Period II (1996-2000)	Period of building new functional strategies in perspective of a free market. Main scope of restructuring programmes included: property restructuring, technological, financial and personnel. The first symptoms of crisis of all Polish metallurgies as a result unfinished programmes of restructuring and restructuring delays, creation of New Programme and the beginning of going out of the crisis situation.
Maturity of enterprises in realisation of restructuring plans (saturation)	Period III (2000-2006)	Going out of the crisis situation of the metallurgical enterprises, first positive effects of restructuring, the enterprises show financial liquidity, the restructuring ally was the increase of steel demand reported by Chinese market, steel companies such as Mittal Steel Poland SA are set up (concentrates 70% of production potential of Polish steel market), the strategic investor is found at: Steelworks Zawiercie (Swedish enterprise Commercial Metal Company), Steelworks Ostrowiec (Spanish Celsa Group) and Steelworks Częstochowa (Industrial Union of Donbas from Ukraine). The next fusions take place, takeovers, and big global metallurgical companies are maintained. Mittal Steel drew up an agreement with Arcelor (June 2006) and ArcelorMittal Poland SA is set up. New investments, investment value on a Polish metallurgic market in 2006 equalled 1 miliard Euros. Steel production remains at the level of about 10 mln of tons per year.
Decline – end of sector restructuring process (saturation)	Period IV (2007 to 2009)	Further reduction in employment in steelworks, continuation of technological restructuring, adjustment of technology to environmental protection principles. The leader on a Polish steel market is ArcelorMittal Poland company. The UE Committee positively evaluates the effects of metallurgic sector restructuring in Poland. In 2008 there is a drop in steel production as an effect of a financial crisis on American market. Companies implement saving programmes based on limitations in production (partial use of production capabilities) and reduction of business costs (outsourcing of unprofitable functions, reduction in employment, putting the final touches on metallurgical furnace etc.)

After the year 1992 all resources and functions of metallurgical companies underwent restructuring. Example of an objective scope of introduced changes in metallurgies (12):

- proprietary-organizational (commercialization and privatisation of metallurgies, reorganisation of enterprises into limited companies, creation of holdings and concerns, capital and contractual outsourcing),
- productive-assortment (increase of importance of processed metallurgical products, increase of the quality of products, development of services associated with metallurgical products, adjustment of metallurgical products to the standards of foreign markets),
- technical-technological (removal of excessive production capabilities, liquidation of old production lines, changes in production technology, a change to COS, purchase of licences and patents),
- financial-capital (debt settlement of companies, maximisation the floating capital, changes in the structure of expenses, cutting costs, increase of importance of foreign capital also in financing the activities of metallurgical enterprises in Poland),
- personnel-payment (decrease in numbers of employees, changes in the structure of employment – increased employment of workers with a higher degree, improve qualification and competence of employees by taking into account enterprise needs, goal management system, increase the importance of non-financial motivation, improve the level of employees engagement in enterprise management),
- managerial-organisational (new organisational schemes of companies, new methods and techniques of work organisation, enterprise management ,e.g. Just in Time, Kanban, 5S, SMED, team work, information-computerised systems supporting enterprise activity, new organisational sections and new functions, e.g. market research, marketing, distribution, customer service, quality assurance, environmental protection).
- In the restructuring process of metallurgical sector in Poland a few phases can be distinguished, such as:
- introduction of restructuring guidelines for companies (1992-1995),

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- introduction of restructuring guidelines for companies (1992-1995),

- increase of the importance of restructuring for individual enterprises (1996-2000),
- maturity that is a full implementation of restructuring strategies in metallurgical enterprises (2000-2006),
- decline – finishing the most important stages of recovery programmes in individual metallurgical companies (2007-2009) – positive evaluation of EU Committee for the effect of restructuring programme in metallurgic sector in Poland.

Table 9.

Life cycle of steel company ArcelorMittal Poland SA (12, p. 22-23).

Phase	Period	Features
Birth (stage I)	2002-2003	Polish Steelworks that is old steelworks: Katowice, T. Sendzimira, Florian i Cedler were consolidated into one holding
Birth (stage II)	2003- June 2006	Polish Steelworks are overtaken by a foreign (British) capital LNM Group, which later was bought by Indian ISPAT and renamed Mittal Steel Company.
Birth (stage III)	June 2006- to 2007	Capital agreement – Mittal - Arcelor. Organizational changes in structure of the new company ArcelorMittal Poland SA.
Growth (stage I)	2008- 2009	Strategic programmes of adjustment of steel company ArcelorMittal Poland SA to the directions of capital group development – gradual changes covering all areas of company functions. In January 2009 the company overtakes the following production companies such as Batory and Królewska Plants.
Growth (stage II)	2009-2010	The company plans to finalise the majority of adjustment changes of overtaken industries to the politics of ArcelorMittal group and to achieve world standards (WCM) in different areas of activity.
Maturity (stage I)	2011-2015	According to prognosis formulated on the basis of ArcelorMittal Poland SA political guidelines - TOP – Teraz o Przyszłości (Now About the Future).

Details related to the process of restructuring of metallurgical sector in Poland are presented in table 8.

The leading company on a Polish market in metallurgical sector is ArcelorMittal Poland SA. The company was founded on a base of Polish Steel Works and as a result of key fusion of foreign capitals, these are Mittal Steel and Arcelor. This company was used to analyse the business life cycle (table 9).

Summary

Presented dependencies of product life cycle and technology life cycle enable the formulation of the following conclusions:

- analysis of interaction may run in a system: environment – consumption – environment or in a system customer – producer – customer,
- concepts of new innovative solutions must concern the product and the technology,
- introduction of new solutions contributes to increase of enterprise market value,
- due to the efficient introduction of innovations an enterprise is able to survive on the competitive and gradually more and more glutted market,
- there are no definite rules how long are the phases of life cycle for example company's life cycle are long and short, some companies exist just from very beginning e.g. Krupa factories, others have been settled recently and gradually strengthen their market position, e.g. ArcelorMittal Poland SA, some have closed down e.g. T.Kościuszki Steelworks in Chorzów,
- companies in metallurgical sector realized their functions in central planning system (until 1989 s in Poland) and in market system (after 1989s),
- in market system companies in metallurgical sector are interested in analysis product and technology life cycle and implement new solutions,
- after the year 1992 all resources and functions of metallurgical companies underwent restructuring and new functions were realized e.g. product marketing.

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Chapter 1.2.

PRODUCTION MANAGEMENT OF CONFIGURABLE PRODUCTS - CASE STUDY OF ROLLER SHUTTERS.

RIADENIE VÝROBY KONFIGUROVATEĽNÝCH VÝROBKOV – PRÍPADOVÁ ŠTÚDIA ROLETY

Janusz MLECZKO *

Key words: configurable products , knowledge database, production planning, mass customization, BOM, TOC

Abstract
According to requirements of the market a great number of small companies are forced to offer a wide product variety and often to respond to the market with customized solutions. At the same time, fast delivery of products is often a key to win orders. Recent developments in Information Technology (IT) made available also for small companies a class of software tools called product configurators which could be integrated with ERP systems. This paper presents production management using a method of generating structures and bill of materials for configurable product. Author focuses on data preparation and computer aided systems. The method enables efficient management of a large number of product variants. The empirical evidence suggests that, in order to exploit the full potential advantages of product configuration, changes in the organization of process planning and support IT systems are needed. This paper reports a case study of the implementation a product configuration software in small and medium (SME) manufacturing enterprises. The case study of ordering and production control of roller shutter is given.

* Janusz Mleczko, Ph.D., Production Engineering Department, University of Bielsko-Biała;
e-mail: jmleczko@ath.bielsko.pl

1. Introduction

For a long time, firms operating in on the contemporary market have been offering a wide variety of products, in order to fulfill the highly changeable demands of their customers. In many industries competitiveness requires efficient design and delivery of large numbers of product variants. One of a kind products or a large number of fixed products often lead to excessive amounts of design and customer specific engineering, or problems with the management of a large number of product variants. In this paper author presents a method for managing large product families as a configurable product.

The utilization of configurable products requires a systematic sales-delivery process and modeling the product family as a configurable product. Instead of explicitly defining a set of product variants in a product family, a configurable product has a configuration model that contains all (or almost all) the information on the possibilities of adapting the product to customer needs. Previously the primary source of competitive advantage for manufacturing companies in many industries used to be related with the price. Therefore all manufacturing strategies were driven by approaches to reduce the cost of products. Technological advances, in manufacturing as well as information, have provided the impetus for changes in many paradigms, including customer expectations. Customers have become more demanding and want products that can meet their specific individual requirements. Thus customization is turning out to be essential to maintain competitive advantage in many industries (Tralix, 2001).

Producing customized products at a low cost, which seemingly is a paradox, is the purpose of many enterprises. Instead of the mass production the mass customization recently appeared. Mass customization relates to the ability to provide customized products or services through flexible processes in high volumes and at reasonably low costs. The concept has emerged in the late 1980s and may be viewed as a natural follow up to processes that have become increasingly flexible and optimized regarding quality and costs. In addition, mass customization appears as an alternative to differentiate companies in a highly competitive and segmented market (Da Silveira et al., 2001).

This main purpose determined as fulfilling customer needs results production in the unit and small batch. In the process of unit and small batch production a very important aspect is the amount of time from production setup to availability to the customer. In the that kind of production enterprises win contracts playing with time of product availability for the customer. In such conditions confirming orders is particularly important. Appearing the Internet and the cooperation in B2B model was a next challenge for many enterprises. Systems of the manufacturing became more opened and required intense IT support. According to appropriate accuracy to confirm orders availability of resources should be taken into consideration. For the correct production run a company needs some resources. They are especially machinery, materials, financial resources, information technology and human resources. One of the main resource's attribute is its availability which is most often constrained by many factors. In the production planning process, the main problem is to allocate resources to orders and jobs in such way to maximize resource utilization and shop-floor productivity as well as minimizing flow times, wastes and costs. The full utilization of resources in practice is very unlikely by reason of many constraints and unforeseen circumstances. So companies, particularly SME, need IT tools efficient solving the above problem not optimal but in the good enough way. This paper presents a case study of the implementation computer aided management system in SME for the roller shutter manufacturing.

2. Problem backround

Past research on product variety management explored multiple solutions to overcome these difficulties: some scholars focused on integrated approach for flexible manufacturing systems (Matta et al., 2001), others on product structure and specification (Eynard et al., 2004), (Ball et al., 2008), mass customization, part family manufacturing and group technology (GT). The concept of Mass Customization (MC) producing customized goods for a mass market has received considerable attention in the research literature (Da Silveira et al., 2001). The fundamental modes of operation for mass customization were given in (MacCarthy et al., 2003). A risk for mass customization termed as ‘‘mass confusion”, which is a metaphor of the burdens for the consumer as a result of attractive but probably overloaded options was also considered (Huffman and Kahn, 1998). More and more, small and medium-sized enterprises (SME) are using software to increase the functionality of their products and offerings. Variability management of software is becoming an interesting topic for SME with expanding portfolios and increasingly complex product structures. While the use of software product lines to resolve high variability is well known in larger organizations, there is less known about the practices in SME (Thörn, 2010).

Manufacturing based classification began to evolve in the 1940s. It is based on the idea that parts do not have to look the same to be similar. Although they may appear to be different, they can be manufactured in the same way. It becomes possible to develop a classification system that groups parts according to their manufacturing characteristics (Houtzeel, 2001), (Ben-Arieh, 1998). The main problem in initiating a group technology based manufacturing system is to group parts into families. Three methods for accomplishing this grouping are (Tatikonda and Wemmerlow, 1992): visual inspection, parts classification and coding, production flow analysis. As the first step, the development of manufacturing groups requires some measure of parts classification. There is a lot of coding and classification systems that are now in the public domain.

Machine-part grouping problem was also considered in many publications (Adenso-Diaz et al., 2005), (Jeon et al., 1998), (Kulkarni and Kiang, 1995), (Owsiński, 2009). This issue is referred to as ” part family & machine cell formation”, “machine part grouping”, ”group technology manufacturing”. The problem arises dividing the set of machines, into subsets and assigning to these subsets operations, in order to optimize a production organization quality criterion. In (Owsiński, 2009) the attempts to solve the problem with clustering methods were outlined. Conception of product configurators are described in literature among others in (Huffman and Kahn, 1998), (Bozarth and McDermott, 1998). Some scholars focused on optimization data preparing and modeling of product structure e.g. (Lamothe et al., 2006), (Sinnema and Deelstra, 2007), (Elgh, 2008) by product configuration process to the process through which the customer’s needs are translated into the product information needed for tendering and manufacturing (typically product cost, bill of materials (BOM), production cycle, etc.). The attention management literature recently devoted to the issue of product configuration is also related to the important software applications. Advances have been incorporated in a new class of software products supporting the product configuration process called product configurators. The software applications are dedicated to web side users, for customers collaborating in B2B systems (Luo et al., 2008), (Slater, 1999).

To utilize commonality underlying product diversity and process variation, it has been widely accepted as a practice to develop product families, in which a set of similar variants share common product and process structures and variety differentiates within these common structures (Jiao et al., 2000). Conception of product configurators are destined for product families.

Fig. 1 illustrates the decision framework of product family design and development along the entire spectrum of product realization according to the concept of design domains. Based on such view, product family design and development encompasses consecutively five domains, namely the customer, functional, physical, process and logistics domains. Product family decision-making involves a series of "what how" mappings between these domains.

The customer domain is characterized by a set of customer needs (CNs) representing segmentation of markets that demand for product families and triggering downstream product family design mappings in a cascading manner. The CNs are first translated into functional requirements (FRs) in the functional domain, in which designers take into account engineering concerns and elaborate these requirements based on available product technologies (Jiao et al., 2007).

The mapping between the customer and functional domains constitutes the frontend issues associated with developing product families. Such a product family definition task is always carried out within an existing product portfolio and manifests itself through those common practices of order configuration and sales force automation.

Product family design solutions are generated in the physical domain by mapping FRs to design parameters (DPs) based on the shared product platform.

This stage involves typical decisions regarding product family design and configuration. At the front-end, the product portfolio articulates detailed achievement of customer satisfaction in the customer domain in the form of specifications of functionality in the functional domain. On the other hand, the main focus of platform-based product family design is the technical feasibility of DPs in terms of fulfilling the specified functionality (Jiao et al., 2007).

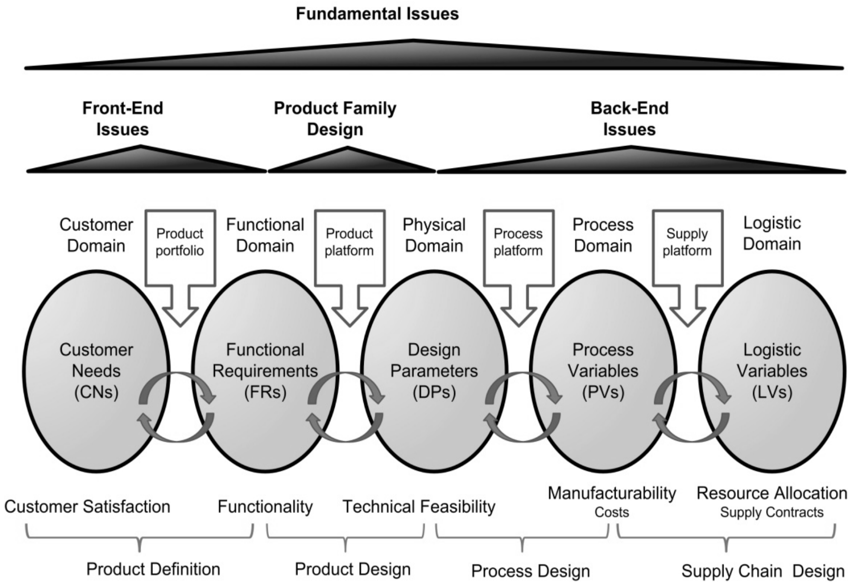


Fig. 1.: ***A holistic view of product family design and development*** *(Jiao et al., 2007)*.

The back-end issues associated with product families involve the process and logistics domains, which are characterized by process variables (PVs) and logistics variables (LVs), respectively. The mapping from DPs to PVs entails the process design task, which must generate manufacturing and production planning within existing process capabilities and utilize repetitions in tooling, setup, equipment, routings, etc. Corresponding to a product platform, production processes can be organized as a process platform in the form of standard routings, thus facilitating production configuration for diverse product family design solutions (Jiao et al., 2000)). Since then main concern in the process domain is manufacturability and cost commitment, process design is the de facto enabler of mass production efficiency. (Jiao et al., 2007)

The paper is structured as follows. First, the studied problem is shortly described, providing information about product customization, B2B business. Then, a description of the products family and the logic that is followed in generating product variants is provided. Then, the main product configuration-related problems faced by the company are discussed. Next description of the main solutions the company envisaged in formalizing its product knowledge and then the changes in the operational management processes and in their performances are discussed. Finally, some concluding remarks are made.

3. Problem formulation

In this case study conducted manufacturing in a small enterprise two goals were included. The first goal is defined as data requirement for configurable products in B2B. The second goal is defined as operational management inside enterprise. The paper focused on the mapping of the activities affected by product configuration before and after the implementation of the product configuration software.

A process of the preparation and automation data for production management of configurable products is also discussed.

To solve the problem a reply to the following question is performed:

- What data for configurable products are needed ?
- What data and what algorithms are necessary for the automatic process of generating production documentation for configurable products?
- What knowledge bases to extend the ERP system for the production of configurable products is necessary?
- Whether it is possible to create the operation production plan for configurable products based on features of the family of products ?

Effective company management requires the right quality data that can be provided by integrated information system. Therefore, the large number of SME have decided to introduced ERP class system although they have recognized that the implementation process is difficult and expensive. However, the alternative solution cannot be easily found (Jacobs and Bendoly, 2003). In the majority of companies the introduced ERP systems were not fulfilling expectations in the area of operational production control. So, companies need efficient tools of decision-making process which could work in “on line” mode.

Such the formulation of the problem serves to emphasize its decision-making nature. Generating bill of materials and routes basing on features of the family of the product is one of main purposes.
The product configuration problem can be formally described as follows:

Definition 1. A configuration problem (CP) is formulated as:

$$CP := \{C, P, Cr, R\} \tag{1}$$

where:

- C – set of components that may constitute a customizable product;
- P – set of properties of components;
- Cr – set of constraints imposed on components due to technical and economical factors.
- R – set of customer requirements, which are usually specified in the forms of constraints.

Definition 2. A configuration Solution (CS) or a configuration is defined as:

$$CS := \{I, V, S\} \tag{2}$$

where:

- I – set of individuals, which are instances of components.
- V – set of values, which are assigned to properties of individuals.
- S – Boolean function defined as :

$$S : \{Cr, R\} \rightarrow \{T, F\} \tag{3}$$

The assignment of I and V makes the expressions Cr and R true.

Definition 3. A configuration engine (Ce) is a function that maps a configuration problem CP to a set of configuration solutions CS:

$$Ce : \{CP\} \rightarrow \{a\ finite\ set\ of\ CS\} \quad (4)$$

Definition 4. A data preparation engine (DPE) is a module that maps a configuration engine (Ce) to sets of BOM and route of production process. It consists from two functions data preparation engine for BOM (DPE_{BOM}) and data preparation engine for route of production prosess (DPE_{RPP}):

$$DPE_{BOM} : \{Ce\} \rightarrow \{a\ finite\ set\ of\ BOM\} \quad (5)$$

$$DPE_{RPP} : \{Ce\} \rightarrow \{a\ finite\ set\ of\ RPP\} \quad (6)$$

Definition 5. Bill of materials (BOM) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, components, parts and the quantities of each needed to manufacture a final product (Reid et al., 2002).

A BOM can define products as they are designed (engineering bill of materials), as they are ordered (sales bill of materials), as they are built (manufacturing bill of materials), or as they are maintained (service bill of materials). For configurable products CBOM is applied. A configurable bill of materials (CBOM) is a form of bill of materials (BOM) used by industries that have multiple options and highly configurable products. The BOM should involve three aspects:(Jiao et al., 2007)

1. Items: the way in which a product is built from purchased parts and/or semi-finished products.

2. "Goes-into" relationships. A goes-into relationship is a relationship between a particular parent and a particular component. A BOM may contain several goes-into relationships, all with the same parent product. All goes-into relationships, together with items, form a hierarchy representing the product structure.

3. Employment: In practical applications, the BOM takes various forms. From different perspectives of business functions, the content and construction of BOM will be different.

4. Solution

According to Fig. 1. the solution of the problem is presented as three issues: front-end issue, product family design and back-end issue. First, an illustrative example is presented.

4.1. Illustrative Example

The examples in this paper is the customization and production of product families: roller shutters manufactured in SME.

The company's offer includes dozens of window covers' group products in interior and exterior systems, including: horizontal, vertical, rolled and pleated. Furthermore, the company as a producer of components to window covers offers a wide scope of details made of plastic, aluminum, steel and wood. Modern, fully automated machine park allows us to maintain the highest, repeatable quality of ready-made element (www.anwis.pl, 2010).

Fig. 2.: Roller shutters *(www.anwis.pl, 2010)*

"The care about the functionality, design, use of modern materials as well as the realization of products made for individual order gives our Clients the full comfort and unlimited arrangements possibilities"(www.anwis.pl, 2010). Roller shutters are one among many of family products (Fig. 2). In Tab. 1. is given technical specification of roller shutters.

Tab. 1.
Technical specification and features of roller shutters *(www.anwis.pl, 2010)*

System	profile's height (mm)	profile's thicness (mm)	weight 1 m^2 (kg)	max width (mm)	max height (mm)	max surface (m2)
PA 39	39,0	9,0	2,80	2800	3000	6,0
PA 41	41,0	8,5	6,83	3800	4200	8,5
PA 45	45,0	9,0	3,00	2900	3500	6,5
PA 52	52,0	13,0	3,50	3700	3800	8,0

4.2. General conception of presented solution

Given a set of predefined components, the task of product configuration is to find a configuration solution satisfying individual needs of customers without violating all constraints imposed on components due to technical and economical factors. Configuration models describing all legal combinations of components include knowledge about the structure of products and knowledge about technical and economical constraints. Additionally, user requirements can be specified in the form of constraints, such as constraints on properties of a component.

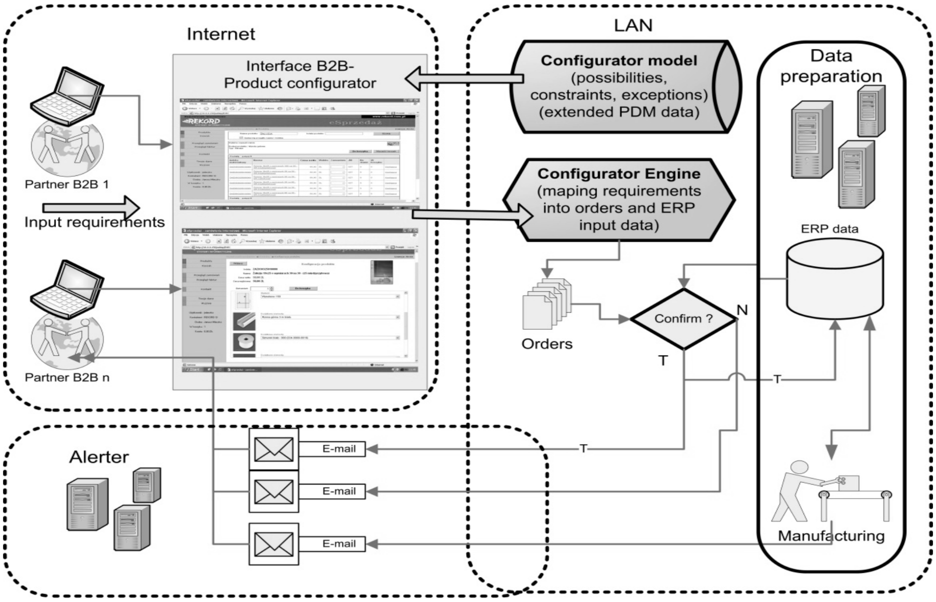


Fig. 3.: General conception of presented solution

Using a problem-solving technology, configuration engines perform actual inference processes with both configuration models and user requirements as the inputs and then generate a configuration as the output. A configuration (or configuration solution) consists of the component individuals, the assignment of values to properties of these individuals and the connection relations among components such that all constraints and customer requirements are satisfied. The architecture of a product configuration system and integration with management information system is shown on Fig. 3. System consists from following elements: interface for B2B partners, configurator model, configurator engine, data preparation engine, ERP system and alerter software.

4.3. Front-end issue

Currently, the front-end issue mainly focuses on interface for B2B partners. Think of configurable products as made-to-order products dynamically developed last years. An Internet created new possibilities for submitting orders directly by the customer. However, building the knowledge base for configurator is a real challenge. Not all companies in the business of roller shutter managed to cope with that problem. A configuration of products based on the customer's requirements and defining requirements "a priori" are the point issue. The next problem constituted into the interface for submitting orders. The interface must be clear, transparent, dynamic, graphical and in correlation to changeable requirements. (see Fig. 4.)

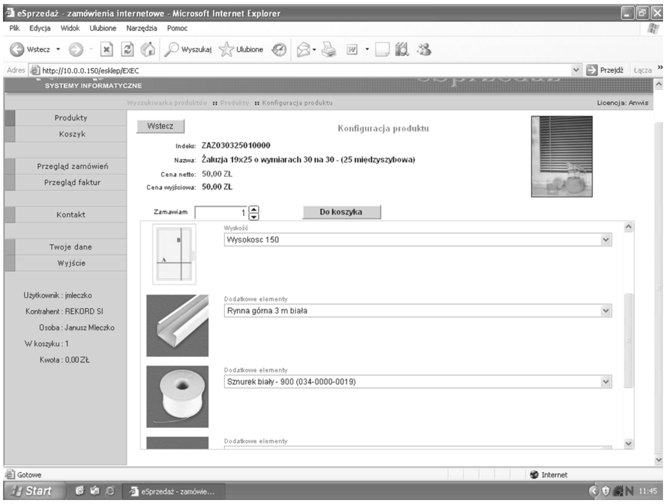


Fig. 4.: Interface of product configurator

For a better idea on how a product configurator works, imagine at the following shopping scenario:

1. A customer navigates through an electronics online catalog until finding a roller shutter that he is interested in. At this stage a search engine of products is needed.
2. Since the chosen product is a dynamic kit, it needs to be configured through an configurator.
3. The customer selects the "*Configure*" link (or a similar link) to interact with the configurator (see more in (www.rekord.com.pl, 2010)). This interaction may be as simple as answering a series of questions or as complex as manually selecting detailed configuration options for the product. At this stage interface of configurator plays an important role.
4. When the customer has completed the interaction, the configurator returns a bill of materials that represents the grouping of items that make

up the fully configured shutter. The customer can then decide to add this configured computer into the shopping cart.

5. The order is sent to the company by web page.
6. The company is confirming the order. The confirmation is visible on the web page. There is also sent alert about confirming or rejection the order.

4.4. Product family design

4.4.1. Configuration model

A configuration model is based on an analysis of the product to be modeled. First thing what user need to do is specifying attributes for the configurable products, like colour, size, kind of drive, etc. Therefore the modeler should have a good understanding of the product. The product should be modeled by product experts in the product development process. The configuration model is an abstraction of the real world product family that is specifically meant for configuration purposes. For example, it may suffice to model the different types of electric motors for rolling shutters as simple phantom (configurable module) and use it repeatedly in many structures. When kind of the drive (manual or electric) is configured, it is enough to decide the type of the engine.

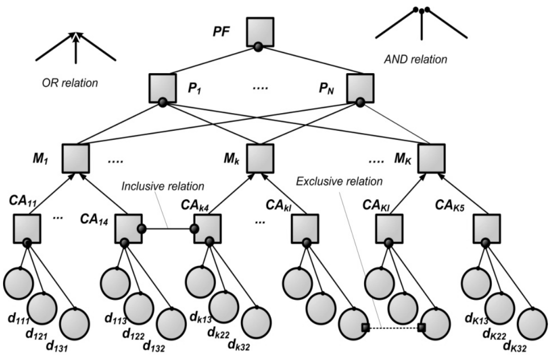


Fig. 5.: AND/OR graph representation of configuration space
(Zhou Jeon et al. 2008)

A dependence of structures in configurator is a next problem. The main requirement for modeling is subjective and requires both practice and good understanding of the product to be modeled and of its usage. It is also evident that different needs lead to different models of the same product. So, modeler must configuration space create.

In this case was implemented solution on the basis AND/OR graph representation (Zhou Jeon et al. 2008). As shown on Fig. 5., configuration space is represented as a AND/OR graph with the root indicating product family (PF on Fig. 5.). The product family is composed of possible configuration solutions $P = \{P_1, P_2, \ldots, P_n\}$ with AND relation. Each solution $P_i | \forall i \epsilon [1, N]$ could be derived through configuring the configurable modules, $M = \{M_1, M_2, \ldots, M_n\}$.

Each configurable module $M_i | \forall i \epsilon [1, K]$ may possess several available module instances $M_k^* = \{CA_{k1}, CA_{k2}, \ldots, CA_{kL_k}\}$ with OR relation, among which, one and only one instance can be selected for a certain configuration solution. While customers always purchase products according to product performances, each module instance is characterized with corresponding product attributes $A = \{a_{kq}\}$, and their values $D = \{d_{kqr}\}$ where d_{kqr} indicates the r^{th} value of the q^{th} attribute associated with the k^{th} module.

Besides the hierarchical relations among these compositions, there are other relations needed to be considered due to their influence on product configuration. They are exclusive and inclusive relations, which could be used to check whether there are conflicts involved in configuration solutions thus enabling to rule out the infeasible solutions in configuration solving.

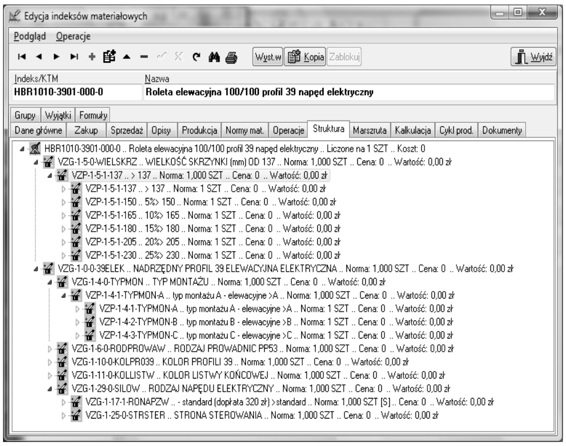


Fig. 6.: Implementation of "AND/OR graph" in PDM module for roller shutter

In the configuration space, the inclusive relation between two compositions implies that when one of the compositions is included in a configuration solution, the other one should also be included. The inclusive relation can be represented as the "if-then" rule: if $C_i = p_{i1}$ then $C_j = p_{j1}$, where C_i and C_j refer to modules (or attributes) while p_{i1} and p_{j1} module instances (or attribute values) associated with $C_i$and C_j. In the configuration space, the exclusive relation between two compositions means that these two compositions are not allowed to coexist in the same configuration solution if $C_i = p_{i1}$ then $C_j \neq p_{j1}$. In this way, the configuration space provides a straightforward way of combining module instances with higher efficiency and form the basis of configuration design for roller shutters manufacturing.

4.4.2. Implementation in software

Implementation of "AND/OR graph" in REKORD.ERP is shown on Fig. 6. It gives an example of product family structure for roller shutter. Because there is a many of possibility for modeling the family of products it is hardly possible to choose the optimal variant. Unfortunately, in practice a big experience of the modeler is required. He must divide what components will be item, what will be configurator with "OR" relation, what will be configurator with "AND" relation and what will be an exception (exclusive relation). Additionally he should build the knowledge base for automatic selections of some parameters e.g. automatic type of the drive depending on the load. (Fig. 7.)

Procedure electric_motor_assortment

```
CREATE OR ALTER PROCEDURE
DP_SILNIK_SPREZYNA (
    kategoria char(3),
    rok smallint,
    symbol varchar(10),
    lp char(3))
returns (
    indeks_silnika varchar(32),
    indeks_sprezyny varchar(32),
    opis varchar(90))
as
declare variable producent
varchar(32);
declare variable rodzaj_napedu
varchar(32);
declare variable spos_zabez
varchar(32);
declare variable szerokosc double
precision;
declare variable wysokosc double
precision;
declare variable kgm2 double
precision;
declare variable z1_kg double
precision;
declare variable z1_obciaz double
precision;
declare variable rodzaj_spr
varchar(32);
declare variable profil char(3);
BEGIN
  /* parametry  pod elektryczne */
if (:profil = '390') then KGM2 = 2.8;
 if (:profil = '410') then KGM2 = 6.83;
 if (:profil = '450') then KGM2 = 3 ;
 if (:profil = '520') then KGM2 = 3.5;
 if (:profil = '521') then KGM2 = 4.75;
 if (:profil = '800') then KGM2 = 6.88;
 if (:profil = '770') then KGM2 = 6;
  select first 1 f_copymid(indeks,9,3)
from m_Zamobcepoz zk
      where
zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and
zk.ROK=:ROK and zk.LP=:LP
          into :Profil;
 if (:profil = '390') then KGM2 = 2.8;
….
  select first 1 ind_zam from
m_ZamobKonfig zk join m_KimWsp
kw on zk.ind_zam=kw.indeks
      where
zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and
zk.ROK=:ROK and zk.LP=:LP and
zk.indeks like "VZG-1-17-4-PRODN%"
          into :PRODUCENT;
  select first 1 ind_zam from
m_ZamobKonfig zk join m_KimWsp
kw on zk.ind_zam=kw.indeks
      where
zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and
zk.ROK=:ROK and zk.LP=:lp and
zk.indeks like "VZG-1-29-0-SILOW%"
          into :RODZAJ_NAPEDU;
  select first 1 ind_zam from
m_ZamobKonfig zk join m_KimWsp
kw on zk.ind_zam=kw.indeks
      where
zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and
zk.ROK=:ROK and zk.LP=:lp and
zk.indeks like "VZG-1-13-%-SPZAB%"
          into :SPOS_ZABEZ;
  select first 1 wymiar_1 , wymiar_2
from D_ZamobKonfig zk where
zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and
zk.ROK=:ROK and zk.LP=:lp
         into
:SZEROKOSC,:WYSOKOSC ;
  Z1_KG =
WYSOKOSC*SZEROKOSC*0.000001
*KGM2;
  if(SPOS_ZABEZ= 'VZG-1-14-0-
BRAK')
     then Z1_OBCIAZ=Z1_KG*1.2;
     else Z1_OBCIAZ=Z1_KG*1.2+5;
  /* dobor silnika */
  select first 1 IND_MAT, opis from
D_MATKONFIG where
Ind_zam_sil=:RODZAJ_NAPEDU and
Ind_zam_prod=:PRODUCENT and
:Z1_OBCIAZ < OBCIAZ_DO AND
:Z1_OBCIAZ >= OBCIAZ_Od
     and :SZEROKOSC between
Szer_od and Szer_do  and dostep='T'
     order by kolejnosc into
:INDEKS_SILNIKA ,:opis;
       suspend;
…..
END
```

Fig. 7.: ***Example of knowledge database procedure***

4.5. Back-end issue

The orders from customers have been divided into 3 groups: orders for not configurable catalog products, orders for catalog configurable products, orders for configurable products with the option of specific requirements. Production management for the first group is in line with standard procedure and is not usually a problem. For management in the next two groups, it is necessary to use the configurator engine. Customization of the configurator engine and data preparation engine are the point of the problem.

4.5.1. Orders for catalog configurable products

So, modeler's task consists on determining what should be an identifier of the product (ID) what configuration of "or/And" type and what components should be exceptions. It is particularly essential because of a huge amount of possible combinations at creating variants. So, inexperienced modeler can cause the failure in implementing the method. In the general case the number of the option is:

$$A_1{}^n * A_2{}^m * \dots * A_l{}^x, \tag{7}$$

where:

$A_1, \dots, A_l$	–	are nodes of the configuration,
l	–	is an amount of nodes and
$n, m, \dots x$	–	are amount of possible selection in individual nodes.

In the traditional approach product IDs for each of the selection options are built. (Fig. 8). Then, for every of the ID documentation is prepared and forwarded to the ERP system. In spite of practicing copying from models this process is very laborious and slower delivery time for customer. In the case of that kind of products such an approach isn't acceptable. The alternative approach requires to apply the data preparation engine (DPE) (Fig. 10.).

The problem of denoting ID is particularly important because of integration with widely used ERP systems**.** In the ERP class system ID is unfortunately necessary both for sales systems, MPS and BOM and another modules.

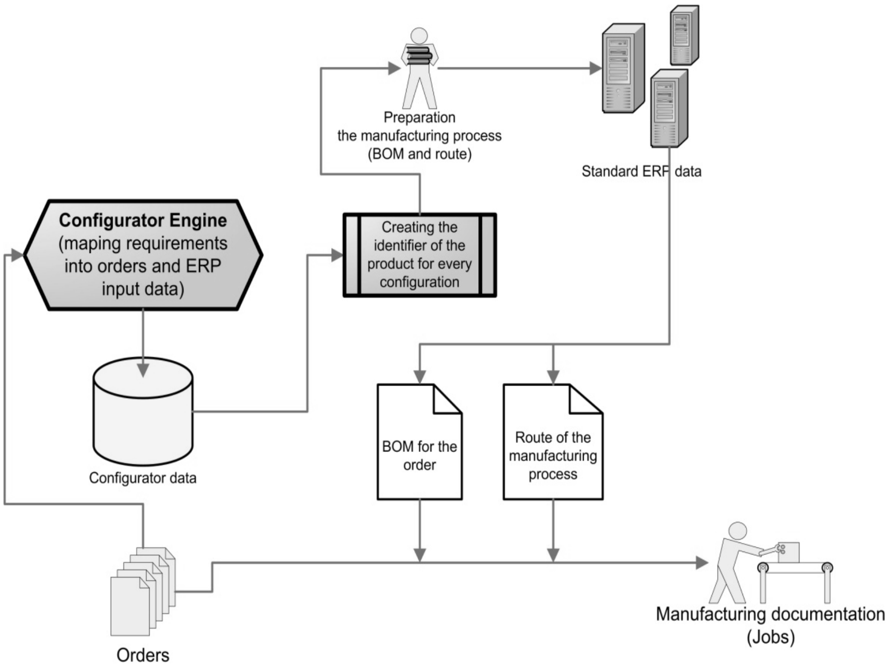


Fig. 8.: The data flow for the catalog configurable product – *scenario no 1.*

If the company doesn't have ERP system adapted for managing the production of configurable products then the only solution is to build a unique product ID for chosen by B2B partner configuration options.

Creating the ID of the product takes place every time at accepting the orders. Creating "a priori" databases of ID is practically impossible. It results from the amount of possible ID. Let's try to count the number of ID for the roller shutters. For the roller shutters parameters for configuration were shown on Tab. 2.

Tab. 2.
Basic parameters for configuration (basic) for roller shutters.

Node	Parameter	Possible values of parameters	Amount of values	Comments
1	***PA System***	{39, 41, 45, 52}	4	Sytem determines the width of the profile.
2	***Width dimension***	From 300 to 3800. From technical reasons producing rollers with width every 1 mm are possible.	about 3500	Maximum roller width depends on the PA system. For example, for PA = 39 is equal to 2800 and for PA = 41 is equal to 3800.
3	***Height dimension***	From 300 to 4200. From technical reasons producing rollers with height every 1 mm are possible.	about 3800	Maximum roller height depends on the PA system. For example, for PA = 39 is equal to 3000 and for PA = 41 is equal to 4200.
4	***Colour of profile***	{brown, dark brown, blue,….}, full range of RAL	About 12 or 1000 (for painted profiles)	Parameter values depend on the supplier of profiles. It is possible also to paint profiles to the any RAL colour
5	***Colour of box***	{brown, dark brown, blue,….}, full range of RAL	About 12 or 1000 (for painted profiles)	Parameter values depend on the supplier of profiles. It is possible also to paint profiles to the any RAL colour
6	***Kind of drive***	{manual using the tape, manual using the handle, manual using the twine, electric}	4	The kind of the drive has a very strong influence on the hierarchical structure of the model configuration. After choice of the kind of the drive the tree of the configuration is separating in distinct branches

Tab. 2. (continued)
Basic parameters for configuration (basic) for roller shutters.

7	***Colour of visible elements of drive***	{brown, dark brown, blue,….},	Between 0 and 100	For electric drive there is no visible elements, For manual drive parameter values depend on the supplier of elements. For example the tape can have practically every pattern.
8	**……**			Depending on the type of roller can occur up to 18 nodes of configuration

The amount of possible product ID has been counted (only for basic options) according to formula (7), and is equal to: 4x3500x3800x1000x1000x4x100 ≈ 2,1 E+16.

Use so built ID would require a very expensive and efficient computer system. In SME such an approaching is possible only for simple products. In most cases, at accepting the orders options of choice are rather described than a product configurator is used.

Another radically different approach is to use only one ID for the entire family of products. Such an assumption significantly complicate the formation of price list and structure of dependences on the configuration hierarchy.

Considering above limitations the following structure of ID was suggested. Denoting the representative of the family of the product was divided in 2 sections: typical ID and stored separately outside the ID configuration features. For the roller ID consists from 4 sections.
(see Fig. 9).

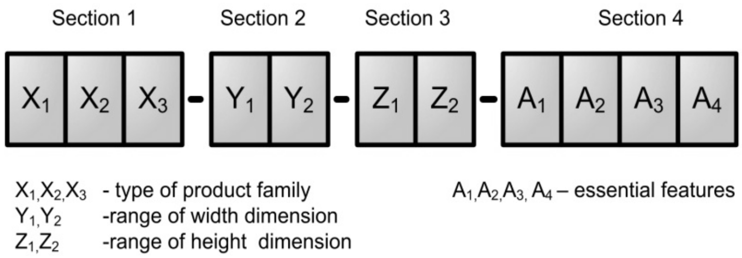


Fig. 9.: ***Sections of product ID***

Example

HBR-10-10-3900

means: HBR roller shutter type, dimensions: width from 990 to 1000, height from 990 to 1000, profile 39, electric drive;

HBR-10-10-3901

means: HBR roller shutter type, dimensions: width from 990 to 1000, height from 990 to 1000, profile 39, manual drive.

Other product features are included in the configuration table. In addition to the configuration table, there is also the table of exceptions. Use the table of exceptions simplifies the building of a hierarchical structure of the configurator. Appearing cross-dependencies in the configurator are eliminated by a table of exceptions.
Having the ERP system adapted to managing configurable products it is possible to apply the solution presented on Fig. 10. Using data preparation engine (DPE) is a crucial element the production management.

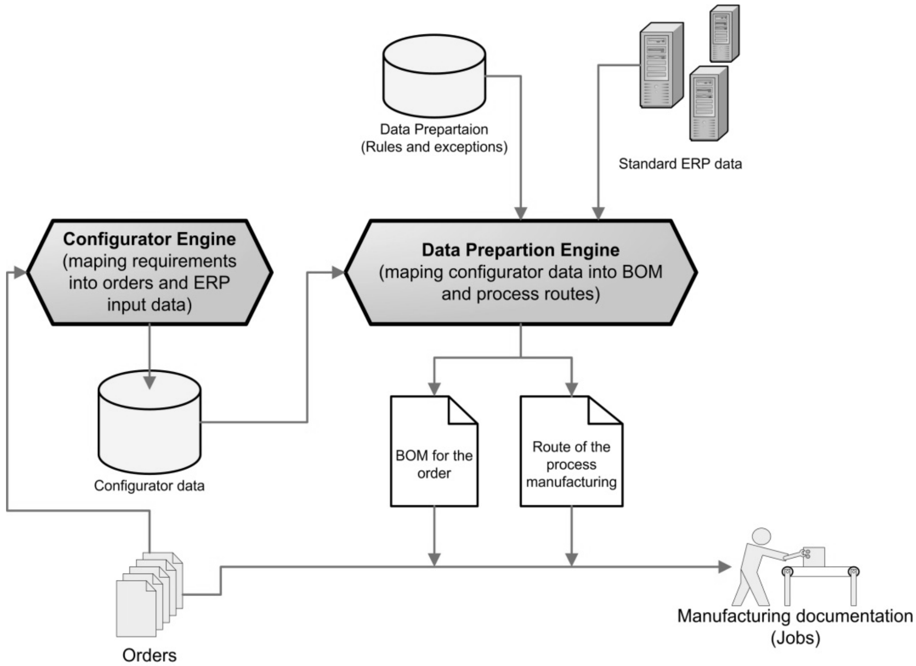


Fig. 10.: The data flow for the catalog configurable product – scenario no 2.

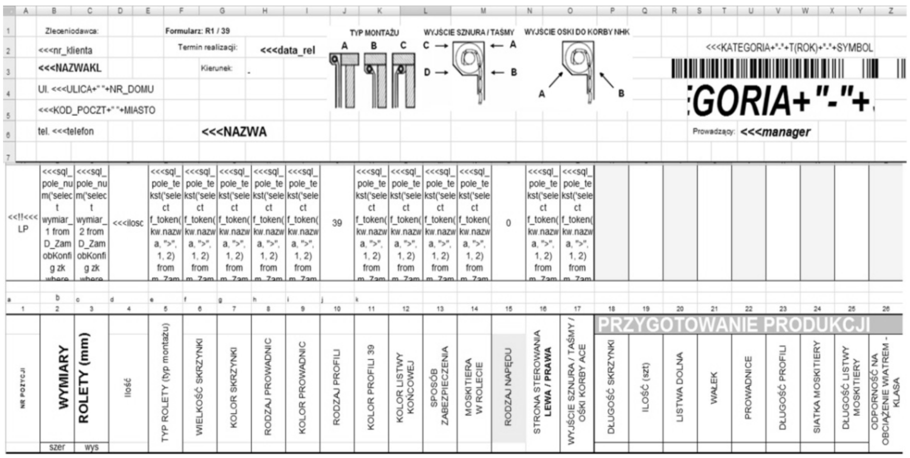


Fig. 11.: Template report of manufacturing process

The data preparation engine is used for the mapping of features of the configuration to the BOM and the route of the manufacturing process. Unfortunately, this approach requires a knowledge base. It is true that the preparation of the database is laborious but manufacturing data are generated automatically.

Preparation of production documentation is to build report templates (Fig. 11.) and then fill them by the data prepared by the DPE. In the first stage DPE calculates the value of BOM and route and in the next stage inserts the value of the technological parameters to the prepared report templates. On Fig. 12. report with manufacturing process with order's data was shown.

FORMULARZ 92/2

ZLECENIE PRODUKCYJNE NA ROLETY ZEWNĘTRZNE - OBUDOWA Heroal - PROFIL ROLETOWY ALUPROF

SYSTEM ELEWACYJNY W SKRZYNKACH 45°

TYP MONTAŻU

Zleceniodawca: BIURO HANDLOWE Bielsko-Biała

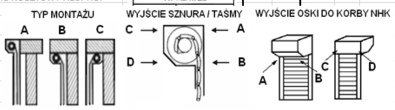
....

Adres/tel:........

NR. ZAMÓWIENIA KLIENT

Data przyjęcia:. 16-7-2010

Termin realizacji 24-7-2010



NR POZYCJI	ILOŚĆ SZTUK	WYMIARY ROLETY (mm) szer	WYMIARY ROLETY (mm) wys	TYP ROLETY	WIELKOŚĆ SKRZYNKI	RODZAJ PROWADNIC	KOLOR SKRZYNKI	KOLOR PROWADNIC	RODZAJ PROFILI	KOLOR PROFILI	KOLOR LISTWY KOŃCOWEJ	MOSKITIERA	ZABEZPIECZENIE: RYGIEL RĘCZNY	RYGIEL AUTOMAT.	ZAMEK BASKWILOWY	WIESZAK BLOKADA	RODZAJ NAPĘDU: SIŁOWNIK	R	T	S	RĘCZNY SZNUROWY	STRONA STEROWANIA L	P	STEROWANIE	PRZYGOTOWANIE PRODUKCJI: DŁUGOŚĆ SKRZYNKI	ILOŚĆ (szt)	LISTWA DOLNA	WAŁEK	PROWADNICE	DŁUGOŚĆ PROFILI	MOSKITIERA: SIATKA MOSKITO HEROAL	LISTWA KOŃCOWA MOSKITO	ODPORNOŚĆ NA OBCIĄŻENIE WIATREM - KLASA	m²	WARTOŚĆ
1	2	3	4	5	6	7	8	9	10	11	12	13	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32	33	31	32	33
1	1	2550	1400	B	180	PR	BIAŁY	BIAŁY	45	BIAŁY	BIAŁY						OXIMO 10/17						X		2540	28	2475	2470	1240	2475			2	3,57	881,11
2	1	2550	1400	B	180	PR	BIAŁY	BIAŁY	45	BIAŁY	BIAŁY						OXIMO 10/17						X		2540	28	2475	2470	1240	2475			2	3,57	911,04
3	1	2550	1400	B	180	PR	BIAŁY	BIAŁY	45	BIAŁY	BIAŁY						OXIMO 10/17						X		2540	28	2475	2470	1240	2475			2	3,57	911,04
4	1	2550	1400	B	180	PR	BIAŁY	BIAŁY	45	BIAŁY	BIAŁY						OXIMO 10/17						X		2540	28	2475	2470	1240	2475			2	3,57	911,04
5	1	2550	1400	B	180	PR	BIAŁY	BIAŁY	45	BIAŁY	BIAŁY						OXIMO 10/17						X		2540	28	2475	2470	1240	2475			2	3,57	911,04
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7	1	2550	1400	B	180	PR	BIAŁY	BIAŁY	45	BIAŁY	BIAŁY						OXIMO 10/17						X		2540	28	2475	2470	1240	2475			2	3,57	881,11
8	1	2550	1400	B	180	PR	BIAŁY	BIAŁY	45	BIAŁY	BIAŁY						OXIMO 10/17						X		2540	28	2475	2470	1240	2475			2	3,57	881,11
9	1	2550	1400	B	180	PR	BIAŁY	BIAŁY	45	BIAŁY	BIAŁY						OXIMO 10/17						X		2540	28	2475	2470	1240	2475			2	3,57	881,11
10	1	2550	1400	B	180	PR	BIAŁY	BIAŁY	45	BIAŁY	BIAŁY						OXIMO 10/17						X		2540	28	2475	2470	1240	2475			2	3,57	881,11
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4526,00	4404,82	8930,82	35,70
ROLETY	**DODATKI**	**SUMA**	**M2**

+ CENTRALIS RTS - 4 szt

KOLUMNA 6 - skrzynki (GÓRA, DÓŁ) - heroal SLK, POKRYWA BOCZNA - GK 5E

KOLUMNA 7 - prowadnice typ MINI HTF (PR), LHTF (KĄT), PP66, PPW66, PP75

KOLUMNA 10 - profile PA39, PE41, PA45, PA52

KOLUMNA 12 - LISTWA KOŃCOWA - systemu ANWIS

Podpis: Tomasz Janusz

Fig. 12.: Report of manufacturing process with order's data.

Example implementation of DPE in the computer system is shown in Fig. 13. There are 3 main sections: ID of raw material or semi-product section, conditions and formula section and amount of raw material section.

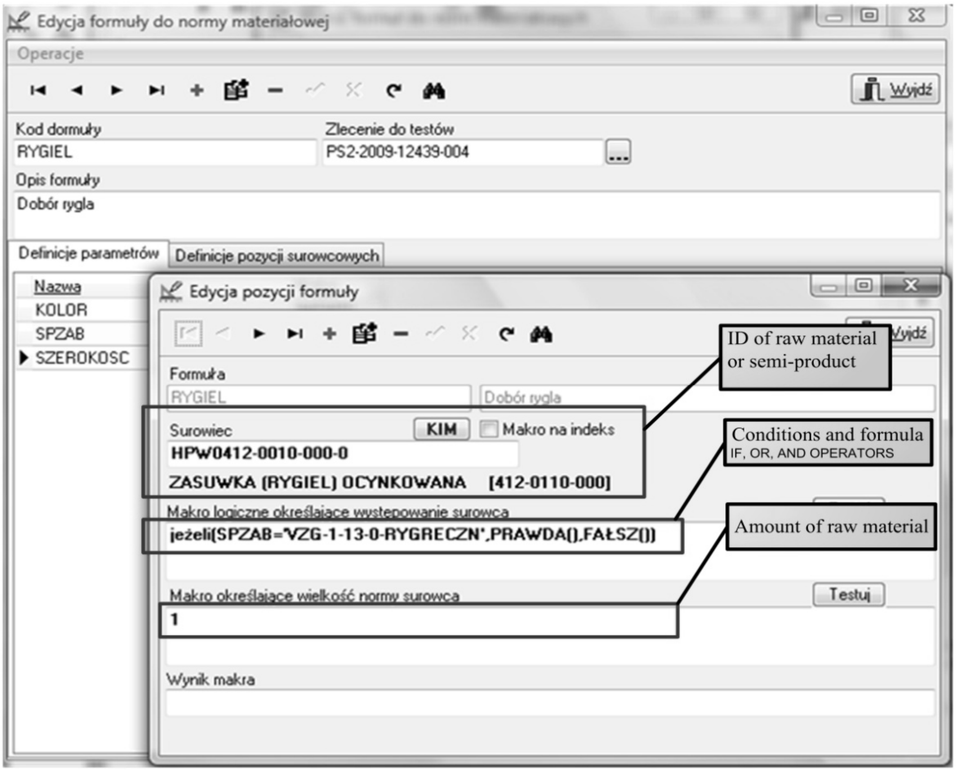

Fig. 13.: Implementation of DPE for BOM.

4.5.2. Orders for configurable products with the option of specific requirements

For products from a group of configurable products with the option of the specific requirements the production management process is more complex (see Fig. 14.). The use of DPE is only one of the first stages of production management. User of computer system operates on the results of DPE. An operator makes changes to the pre-created by the DPE BOM or route of the manufacturing process. The user also makes agreeing as for technical possibilities and price of implementing specific requirements. Then finally an order is confirmed. After making changes data is redirected to ERP where the standard support follows.

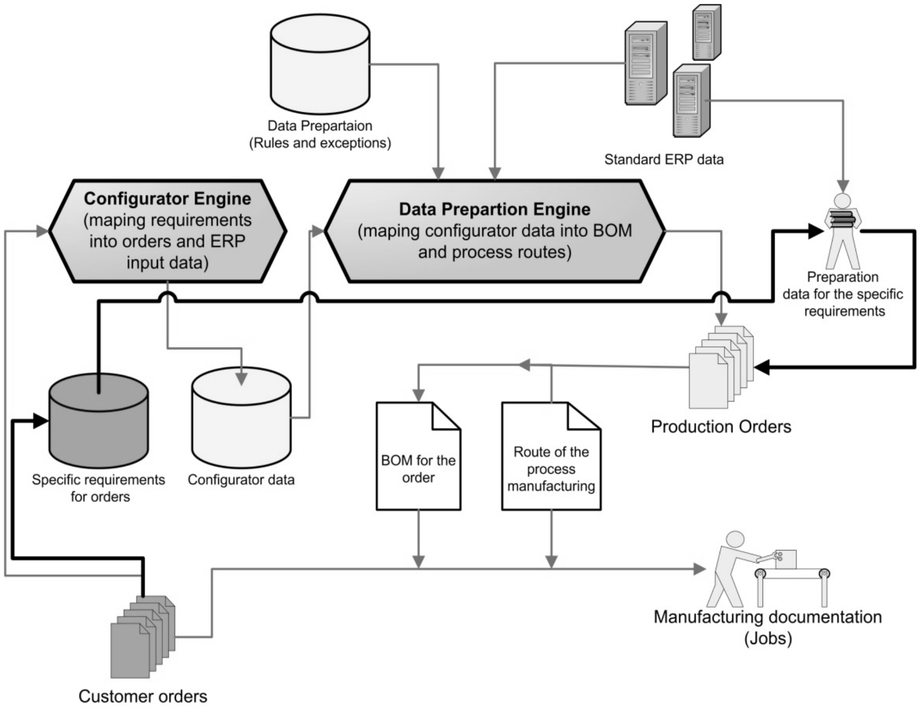

Fig. 14.: The data flow for configurable product with the option of specific requirements

4.5.3. Resource constraints

Standard methods of planning and controlling the production may have limited applying only. A lack of the appropriate quality of data is a reason of limitations at the stage of accepting the commission. Since the BOM and route data are provided by DPE so the standard procedure of balancing resources has nothing to work with. In this case applying Theory of Constraints (TOC) assumptions is a good enough solution. In TOC monitoring the bottleneck is a key issue. Basing on the load of the bottleneck scheduling dates of confirming orders and the realization of the manufacturing process is possible (see Fig. 15.).

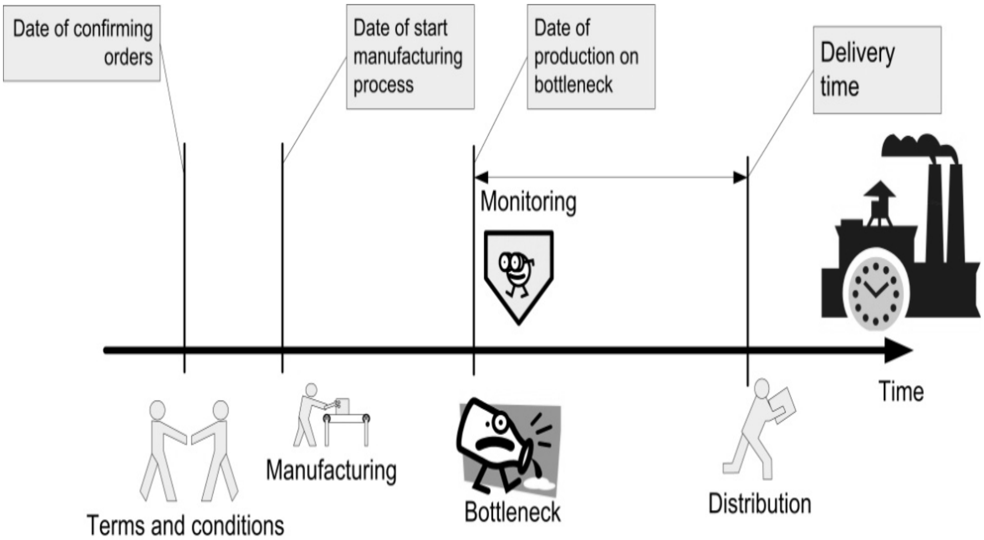

Fig. 15.: Monitoring the bottleneck

Key to the whole planning process and confirmation orders is to monitor the overload of a bottleneck (Fig. 16.). Data on loads are shown on this screen.

This screen is literally monitor 46" visible to all employees of the sales department. It looks like the screen on the air terminal departure hall. On one pivot are visible bottlenecks (group of manufacturing various products). The second axis is the timeline. In this case, it is aggregated into the daily arrangement. On crossing the pivot a daily load for the bottlenecks are visible. Additionally with colours exploiting the availability was emphasized. The colour red means exceeded availability, purple availability from 100 to 90 and so on. These limits result from the current availability and it is possible to control them.

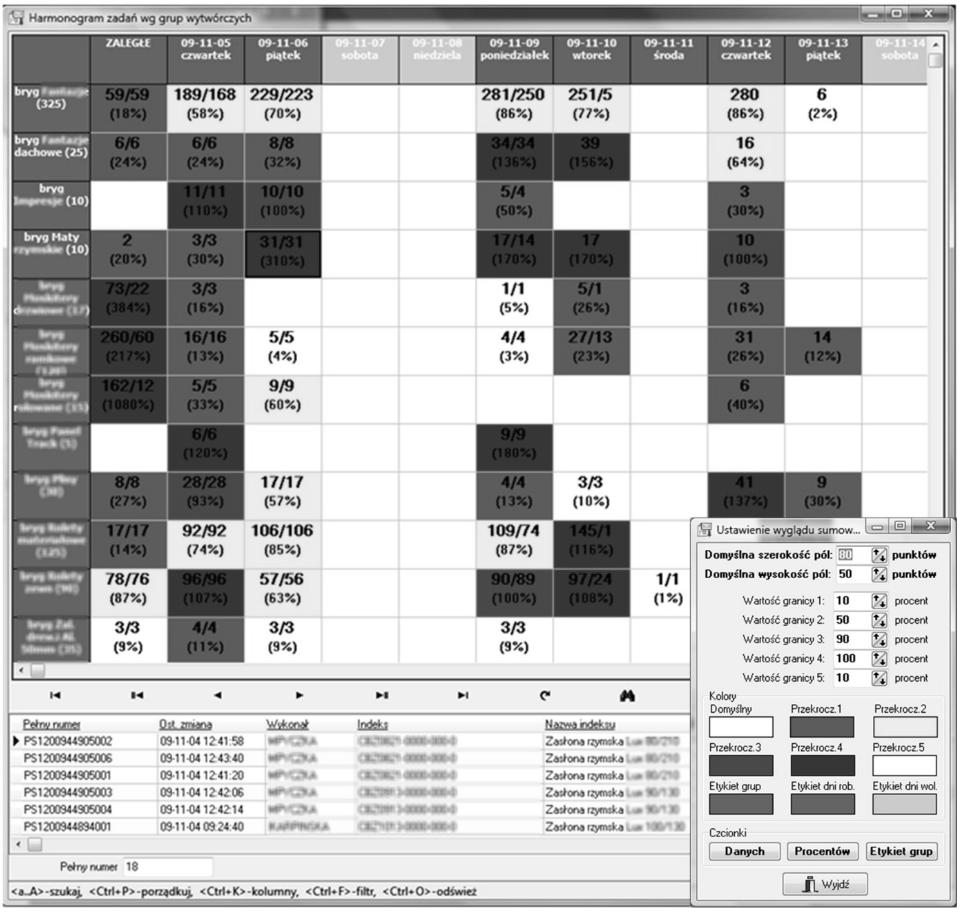

Fig. 16.: Screen with the visualisation of loads for bottlenecks

In a bottom of the screen are given the contracts for which limits have been exceeded. The order of viewing orders is not accidental, it is a set ordered according to the date of the last request (final changes of the data in the computer system). In view of such a setting, employees of the sales department can quickly find the "guilty" of such excess. In this case operator – the salesman must move dates of the order or split it to smaller fragments or make agreeing with the production department. In the case of important orders the work on the bottleneck takes place in overtime.

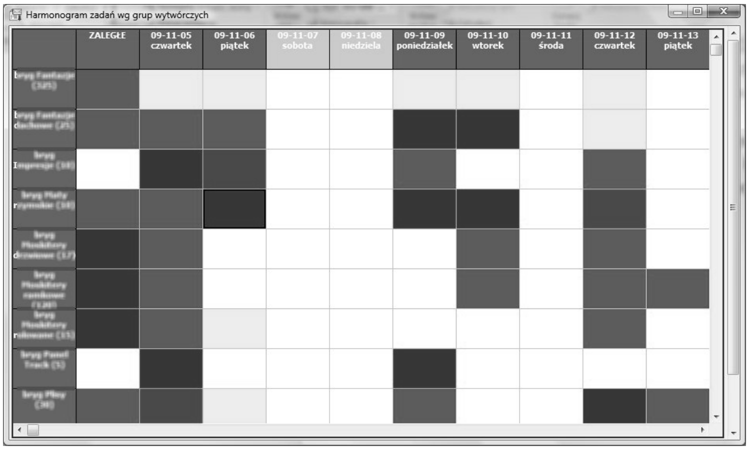

Fig. 17.: Screen simplified for the B2B partners

Another issue is the screen for production control department. Head of production department will use exactly the same screen, but it needs to put the information about the realization of so far accepted orders. Such an arrangement lets the configuration of parameters for shaping the appearance of the window depending on needs for users. Considered is to show the schedule for B2B customers in the web page with access to separated information. Not always, the company will want to share information about their current load. The client could use it as an argument in price negotiations. Shown a productive capacity can find only these dates which time offs have. Also can be blocked accepting of the term of the contract with the date that the buffer is less than a preset time. It means that it is possible to apply the principle of "up to 5 days we will process all orders the target customer". It also may also be shown in the B2B information system. Does not allow to accept the orders of the dates below "today+ 5”. The appearance of the screen for B2B partners is showing Fig. 17.

4.5.4. Production control

Optimal arranging and scheduling tasks is one of the most important problems of production control. The production cycle consists of, among others: the processing time and setup time. Despite using modern management techniques e.g. SMED (Single Minute Exchange of Die) technique, in the conditions of unit production in SME, setup time is significant. In the examined companies of the SME sector the relationship between setup time to processing time is still high and amounts from a few to several per cent of the processing time. The above research inspired the author to prepare a method of setup time based on the similarity of the parts. In order to do this a classifier of a new kind was introduced – the classifier works at the level of process in the operation production plan. The objective of the classifier is to aggregate process into organizationally similar groups. It allows production tasks inside groups: in sequences, without changeovers or by significantly shortening the setup process.

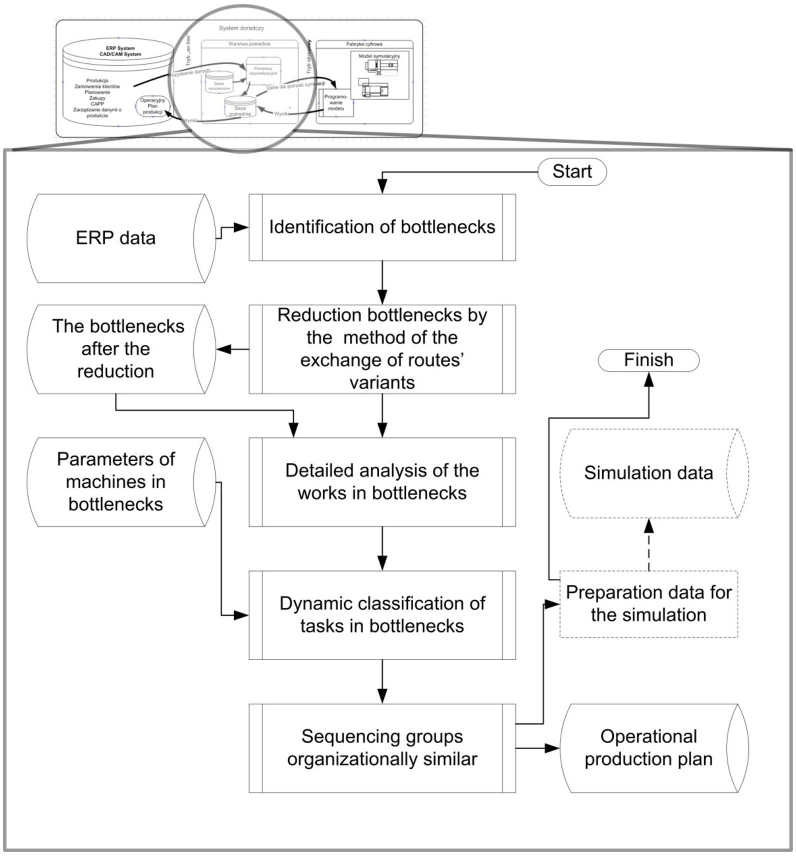

Fig. 18.: Conception of dynamic classification tasks.

The above classification is based on features of tasks having influence on changeover times and optimization of tasks arrangement. Using the standard classifiers, used for Group Technology (GT), for this purpose is not sufficient and in some cases can be harmful.

The principled conception consists of applying a computer system consisting of three elements (see Fig. 18.):

1. ERP class system - collecting primary data about the product and production plans (e.g. orders from customers, the database of machines and devices, routes of production process, the workers and their qualifications),
2. module of grouping and arranging tasks and operational controlling, working in an „on line” mode,
3. module of the simulation being an element of the digital factory - working in a periodic – “off line” mode. This module is destined for the periodic verification of the method.

Focusing on the work bottleneck and improving it is the essence of this approach. This approach corresponds with the assumptions of the theory of constraints (TOC) (Goldratt and Cox, 2002), (Davies et al., 2005). Increasing the productivity of the bottleneck follows from the dynamic classification of tasks in the operational production plan.

A periodic simulation of the bottleneck is an additional element providing the effectiveness of the method. Using the tools of simulation in the "on line” mode demands the purchase, by enterprises, of such systems. At present costs of the license are too high for this approach. So, applying the periodic mode is a good enough solution. Automatic data preparation through the module of middleware is additionally improving the method. Optimization of the daily production plans is based on two-level division of scheduling and arranging tasks. The first step is scheduling backwards without balancing the resources (Figure 2). It allows the system to find bottlenecks. The next step is to focus on the bottlenecks. It is possible to reduce bottlenecks through the exchange of process’ alternatives. The third step is scheduling backwards with balancing the resources. As a result of this action we receive our daily work plan. The further processing is applied to operation plans from the nearest period in the sets of tasks for the given workstation group – the machine group. The length of the period depends on the production type and on the articles produced. In the examined enterprises, in regard to the conditions of unit and small batch production, the period of processing assumes values from 1 to 5 working days. Tasks of the operational production plan were subject to grouping. As a criterion of grouping the most crucial features from the perspective of changeover time were assumed. After task grouping the group is manufactured without a division into fragmentary tasks. With such an arrangement the preparation-finishing times are shortened.

This results not in the effect of implementing tasks in the first day of the next day round but in the arranged groups. As a limitation to the assignment to groups the organization parameters were assumed, such as the delivery time, the task priority, customer code and operation release. The assumption of limitation disturbs the schedule of tasks in a way which does not give side effects in the form of lengthening the cycle of some orders – while the effect of aggregation results in a reduction of work consumption mainly on the side of changeovers times. The fact of introducing the positive feed-back into the system leads to fast consideration of disturbance (in plus or minus) in the next day schedule.

The basic element of the above method is defining features of the article which have an impact on the changeover times. The above features are defined from the perspective of workstations and process production operations.

For example, for the varnishing line, the major influence on the changeover time is the colour of the varnished elements. Regardless of shape (which does have an influence on the processing time) if in the set of tasks there are elements painted the same colour then the line will not be rearmed. Using the standard construction classifier in this case – where the subject of classification is an element and not the operation can have unwanted effects. The groups would be created for elements of the same kind.

When designing the production process we do not know in what sequence the elements will be made and as a result we assign the full setup time in the base. While, if we arranged the tasks properly we could lower the setup times to a greater extent. Preparation setup times cannot be lowered to zero but let us assume that we are able to assess the lowering of setup times for the remaining elements which constitute such a prepared group.

The assignment into the groups is not limited. The basic limitation is the demanded production time. The group cannot consist of too many elements because while performing the tasks for the whole group we perform them faster than is needed and we absorb the resources. Although we shorten work consumption we lengthen the unit production time. We are searching for an optimum in a multi-criterion optimization of the length of cycles, work consumption and production costs. In fact, the process of classification itself has a dynamic character which depends on the organizational conditions. Creating such groups in a manual way would not be useful either, which is why it requires IT support. This method could even be named as semi-automatic one.

5. Conclusions

Managing product families consisting of a large set of product variants as configurable products requires defining a configuration model. The author presented a conception for configuration models and gave short guide on using the concepts. The concepts and modeling guidelines for them were validated with success in SME for roller shutter. Information system support is necessary for modeling products, particularly for configurator available in the Internet for B2B partners. Modeling sets new requirements for the designer. In addition to having a good understanding of the product, a designer should be familiar with object oriented modeling. The main benefit there would be improving communication within the product development team and to other functions of the company, e.g. salesmen. The benefits also include the use of the knowledge database additional functions, structure and the related design constraints during the product development. Product configurator adapted to the ERP system management and B2B partners interface is the key to success in the implementation of the method in the production practice.

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Chapter 1.3.

PROGRESÍVNE PROJEKTOVANIE PRACOVÍSK

PROGRESSIVE WORK PLACE DESIGN

Branislav MIČIETA[1], Ľuboslav DULINA[2]

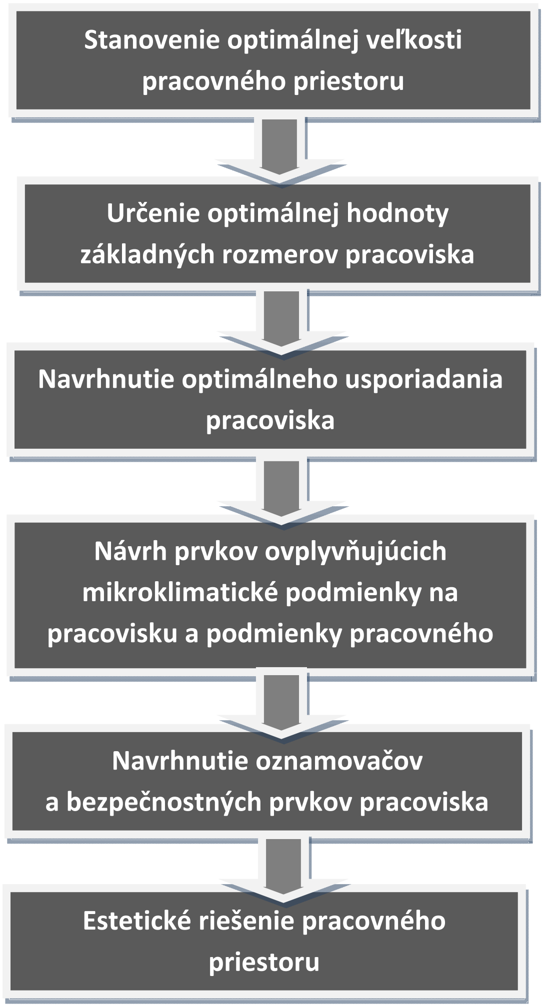
Kľúčové slová: ergonómia, detailné projektovanie pracovísk, človek, práca

Abstrakt
V štruktúre predmetu skúmania ergonómie je na prvom mieste človek. Z toho vyplýva, že ergonomické zásady projektovania pracovísk a pracovného prostredia sú zamerané na vytvorenie čo najlepších podmienok pre zamestnanca v pracovnom procese. Detailné projektovanie pracovísk je v priemyselných podnikoch stále viac žiadané. Vyplýva to nie len z dôvodu zlepšenia pracovných podmienok, ale aj z dôvodu prepojenosti zdravotných aspektov pracovnej činnosti na ekonomické faktory a produktivitu. V článku je popísaný komplexný postup pre ergonomické projektovanie pracovísk tak, aby boli pri zvyšovaní produktivity práce rešpektované zásady jej humanizácie. Zvládnutie komplexného ergonomického prístupu v projektovaní pracovísk následne otvára priestor aj pre aplikáciu progresívnych nástrojov v oblasti digitálneho podniku, ktoré pomôžu tento postup zrýchliť, zefektívniť ale tiež lepšie vizualizovať z pohľadu propagačného ale aj významového (detekcia kolízií a pod.)

[1] **Prof. Ing. Branislav Mičieta**, **PhD.**, Industrial Engineering Department, Faculty of Mechanical Engineering, University of Žilina, Univerzitná 1, 010 26 Žilina, Slovak Republic, tel. +421-041-5132702,
e-mail: branislav.micieta@fstroj.uniza.sk http://fstroj.utc.sk/web/kpi/
[2] **Ing.Ľuboslav Dulina, PhD.,** Industrial Engineering Department, Faculty of Mechanical Engineering, University of Žilina, Univerzitná 1, 010 26 Žilina, Slovak Republic, tel. +421-04-15132722,
e-mail: luboslav.dulina@fstroj.uniza.sk http://fstroj.utc.sk/web/kpi/

1. Projektovanie pracovísk

Proces projektovania pracoviska je možné zhrnúť do šiestich základných okruhov činností (Obr. 1).



Obr. 1.: Okruhy projektovania pracovísk

V súvislosti s projektovaním pracoviska a jeho celkového pracovného priestoru v zmysle ergonomických zásad ovplyvňujú jeho tvorbu najmä nasledovné faktory:

- rozmery ľudského tela, a možnosti pohybu jednotlivých častí tela,
- počet zamestnancov,
- faktory týkajúce sa užívateľa (vek, pohlavie, fyzická zdatnosť ...),
- bezpečnostné a hygienické predpisy, smernice, nariadenia,
- psychologicko-fyziologické informácie,
- nutná dĺžka pobytu v priestore,
- častosť používania priestoru (vplyv škodlivín na človeka),
- charakter vykonávanej pracovnej činnosti v priestore,
- pracovná poloha,
- vybavenie pracoviska.

2. Stanovenie optimálnej veľkosti pracovného priestoru

Pracovný priestor je definovaný ako vymedzená časť priestoru, v ktorom zamestnanec alebo pracovná skupina vykonáva svoju činnosť. Čím lepšie je pracovný priestor prispôsobený predpokladanej práci človeka, tým vyššia je aj kultúra a produktivita jeho práce.

Veľkosť a tvar pracovísk sú obvykle veľmi rozmanité. Závisí to od konkrétneho charakteru výrobného procesu.

Z hľadiska veľkosti, tvaru a usporiadania rozoznávame a posudzujeme v pracovnom priestore tieto kategórie plôch:

- základnú strojovú plochu – plochu na ktorej je umiestnené strojové zariadenie,
- plochu na skladovanie materiálu,
- plochu na dopravu materiálu (dopravné cesty),
- plochu na manipuláciu (najmä na medzioperačnú manipuláciu),
- plochu na prípravu prípravkov a nástrojov,
- plochu na údržbu a opravy.

Riešenie pracovného priestoru a pracovného zariadenia musí byť také, aby nedochádzalo k zbytočnému alebo nadmernému namáhaniu svalov, kĺbov, väzov, dýchacieho a obehového systému. Silové požiadavky musia byť vo fyziologicky prijateľných hraniciach. Telesné pohyby by mali mať prirodzený rytmus. Poloha tela, uplatňovanie sily a pohyb tela by mali byť vo vzájomnej harmónii.

Pracovné miestnosti musia mať dostatočnú podlahovú plochu, výšku a voľný priestor, aby sa zamestnancom umožnilo vykonávať prácu bez ohrozenia ich bezpečnosti, zdravia alebo pracovnej pohody. Rozmery voľného neobsadeného priestoru sa musia vypočítať tak, aby umožňovali zamestnancom dostatočnú voľnosť pohybu pri vykonávaní ich práce. Ak to z osobitných dôvodov nemožno dosiahnuť na pracovisku musí mať zamestnanec zabezpečenú dostatočnú voľnosť pohybu v blízkosti svojho pracoviska. Jednotlivé plošné výmery nemožno vždy jednoznačne ohraničiť, pretože v priebehu výrobného procesu nastáva prelínanie jednotlivých činiteľov a prvkov celkovej plochy pracoviska. Minimálna výmera veľkosti plochy a priestoru pracoviska je stanovená v normách a hygienických predpisoch (ďalej uvádzam hodnoty, ktoré sú v zmysle platných noriem na území SR). Pre jedného zamestnanca má byť na pracovisku voľná podlahová plocha minimálne 2 m^2 okrem zariadení a spojovacej cesty. Šírka voľnej plochy na pohyb nemá byť v žiadnom mieste zúžená na menej ako 1m. V závislosti od výrobných pochodov môže hygienická služba určiť aj požiadavku na väčší vzdušný priestor a väčšiu výmeru podlahovej plochy. Na jedného zamestnanca musí pripadnúť vzdušný priestor najmenej podľa tabuľky 1. Veľkosť vzdušného priestoru pripadajúceho na jedného zamestnanca závisí od zvolenej pracovnej polohy.

Tab. 1

Veľkosť vzdušného priestoru pripadajúceho na 1 zamestnanca

Druh práce	Vzdušný priestor (m^3)
práca v sede	12
práca v stoji	15
ťažká telesná práca	18

Svetlá výška pracovísk na ktorých sa vykonáva dlhodobá práca, v závislosti od veľkosti plochy je uvedená v tabuľke 2. V prípade, že miestnosť má šikmý strop, musí mať takúto výšku najnižšia strana miestnosti. Svetlá výška miestností so šikmými stropmi má byť aspoň nad polovicou podlahovej plochy 2,3 m. Svetlá výška pracovísk, na ktorých sa vykonáva práca po dobu kratšiu ako 4 hodiny za pracovnú zmenu, alebo občasná práca, nemá byť nižšia ako 2,1 m.

Tab. 2

Výška a plocha pracoviska

Plocha (m^2)	Svetlá výška pracoviska od podlahy (m)
do 50	najmenej 2,6
51 – 100	2,7
101 - 2000	3,0
nad 2000	3,25

Pracovný priestor, jeho usporiadanie, tvar a veľkosť sú ovplyvnené predovšetkým:

- obsluhovaným technickým zariadením a pracovnými podmienkami,
- človekom samým, teda jeho rozmermi, pracovnou polohou tela, pohyblivosťou končatín a počtom osôb.

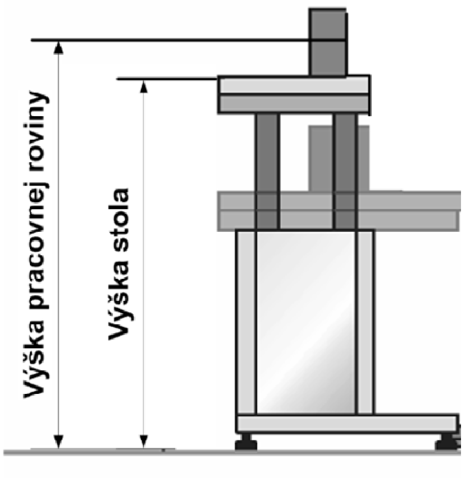
Hospodárenie s pracovnou plochou a iné ekonomické hľadiská pôsobia často na isté obmedzenia pohybovej voľnosti pri práci. Kritérium pre navrhovanie veľkosti pracovnej, príp. podlahovej plochy, alebo pre isté obmedzovanie priestoru pre potrebnú činnosť človeka, bude hlavne požiadavka bezpečnosti a hygieny práce pri pracovnom výkone a potrebné pohodlie pri pohybových úkonoch.

3. Určenie optimálnej hodnoty základných rozmerov pracoviska

3.1. Výška pracovnej roviny

Veľkosť a výška pracovnej roviny nemusí byť rovnaká ako výška pracovného stola. Je určená miestom na stroji, alebo pracovným predmetom, ku ktorému sa vzťahuje väčšina ručne vykonávaných prác.

Pracovná výška, v ktorej človek vykonáva pracovnú činnosť, sa definuje ako vertikálna vzdialenosť pracovnej plochy od podlahy. Výška pracovnej plochy nemusí byť totožná s výškou pracovného stola (obr. 2).



Obr. 2.: Výška pracovnej roviny

Výška pracovnej manipulačnej roviny musí zodpovedať telesným rozmerom zamestnanca, základnej pracovnej polohe, hmotnosti predmetov, bremien a podobne, ktoré sa používajú pri práci, ako aj zrakovým nárokom na prácu.

Výška pracovnej roviny musí byť nastaviteľná, aby umožnila prácu „malej žene“ aj „veľkému mužovi“.

Pri práci, ktorá vyžaduje zvýšené nároky na zrak, napríklad práca s drobnými predmetmi, súčiastkami a podobne sa výška pracovnej roviny zvyšuje približne o *10* až *20 cm*, pričom treba zabezpečiť podopretie predlaktí. Pri práci, pri ktorej sa manipuluje s predmetmi ťažšími ako *2 kg*, pri práci v stoji sa manipulačná rovina znižuje približne o *10* až *20 cm*.

V tabuľke 3 sú uvedené odporúčané hodnoty pre výšku pracovnej roviny v závislosti od pracovnej polohy a pohlavia zamestnanca.

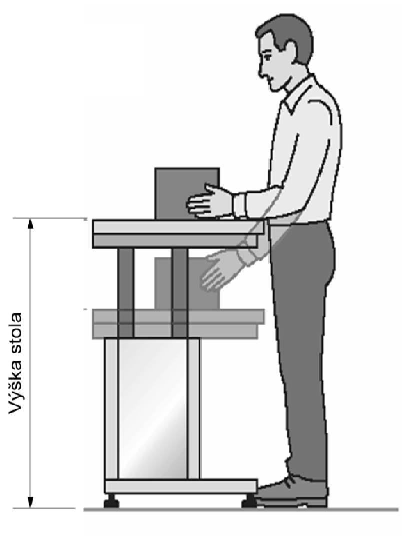
Tab. 3

Optimálna výška pracovnej roviny

Optimálna výška pracovnej roviny (mm)		
	stoj	**sed (nad sedadlom)**
Muži	1120 – 1180	220 – 310
Ženy	930 – 1080	210 – 300

Výška pracovnej plochy stola je ovplyvnená charakterom pracovnej činnosti, pracovnou polohou, výškou tela zamestnanca a zornou vzdialenosťou. Odporúčané hodnoty pre výšku pracovného stola v závislosti od pracovnej polohy a od pohlavia zamestnanca sú uvedené na obr. 3

Práca v stoji		
	jemná práca	**hrubá práca**
Muži	100-115 cm	220-310 cm
Ženy	95-105 cm	210-310 cm



Obr. 3.: Výška pracovnej plochy stola

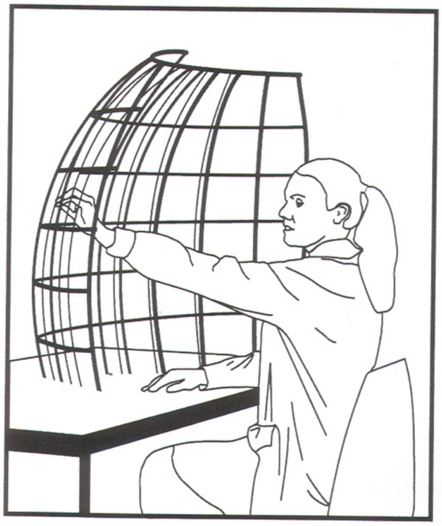
3.2. Pohybový priestor

Pohybovým priestorom na pracovisku rozumieme priestor, v ktorom môžeme vykonávať pracovné činnosti. Rozlišujeme:

- manipulačný (ručný priestor),
- pedipulačný (priestor pre nohy).

Manipulačný priestor je priestor, ktorý je daný manipulačnou rovinou. Manipulačná rovina je rovina preložená miestom najčastejšie vykonávaného ručného pohybu, v ktorom sa vykonáva väčšina úkonov.

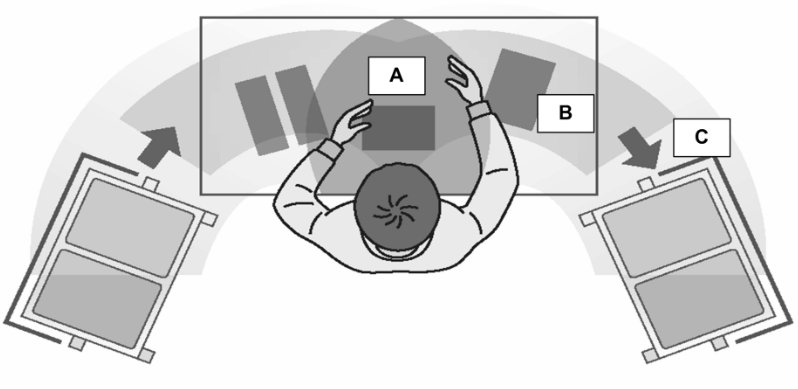
Manipulačný priestor (obr. 4) je dosiahnuteľný stredom dlane a je ohraničený guľovými plochami o polomere funkčnej dĺžky horných končatín a vodorovnými rovinami prechádzajúcimi vo výške ramien a lakťových kĺbov.



Obr. 4.: Pohybový priestor horných končatín (13)

Z ergonomického hľadiska rozoznávame (obr. 5):

- oblasť A – optimálny pohybový priestor pre obe ruky: vhodný pre umiestnenie výrobkov, ktoré sa používajú najčastejšie, pretože v tomto priestore obidve ruky pracujú v zornom poli,
- oblasť B – vhodný pohybový priestor pre obe ruky: vhodný pre umiestnenie takých nástrojov a predmetov, na ktoré väčšinou siaha iba jedna,
- oblasť C – nevhodný pohybový priestor pre obe ruky.



Obr. 5.: Oblasti manipulačného priestoru

Veľkosť jednotlivých pohybových priestorov, slúžiacich na umiestnenie ovládačov, náradia a miesta vykonávania pracovných operácií súvisí s mierou opakovania pracovných pohybov, ktoré sa delia na:

- časté, t. j. opakované najmenej 40-krát za zmenu (napr. pri obsluhe stroja s ovládačmi používanými trvalo);
- občasné, vykonávané menej ako 40-krát a viac ako 20-krát za zmenu (napr. pri obsluhe stroja s ovládačmi používanými často);
- zriedkavé, ktoré sa opakujú menej ako 20-krát za zmenu (napr. pri obsluhe stroja s ovládačmi používanými zriedkavo).

Základné rozmery pohybového priestoru horných končatín sú uvedené v tabuľke 4 a orientačné zobrazenie pohybového priestoru horných končatín v horizontálnej rovine je uvedené na obr. 6.

Rozmiestnenie zásobníkov, komponentov, náradia a iných prvkov, s ktorými zamestnanec manipuluje by mali byť umiestnené v oblasti danej rozmermi predpísanými v tabuľke. To znamená, že ak je zamestnanec muž, jeho manipulačný priestor predstavuje plochu 25 x 70 cm a v tejto zóne, v maximálnej výške 35 cm nad manipulačnou plochou, by mal mať uložené všetky potrebné manipulačné prvky. Návrh optimálneho usporiadania pracovísk i funkčných častí strojov a zariadení musí prihliadať i na možnosti dosahu rúk pri otáčaní vo vertikálnej rovine. Obdobne ako v horizontálnej rovine, i v tomto prípade rozoznávame normálnu a maximálnu pracovnú zónu. Rozmery kružníc, ktoré opisujú ruky pri otáčaní, sú závislé od pracovnej polohy, t. j. polohy človeka v sede alebo v stoji. V pracovnej polohe sed sa plecia podstatne ťažšie pohybujú v kĺboch ako pri polohe stoj, a preto i kružnice, ktoré opisujú ruky, majú menší polomer ako v polohe stoj.

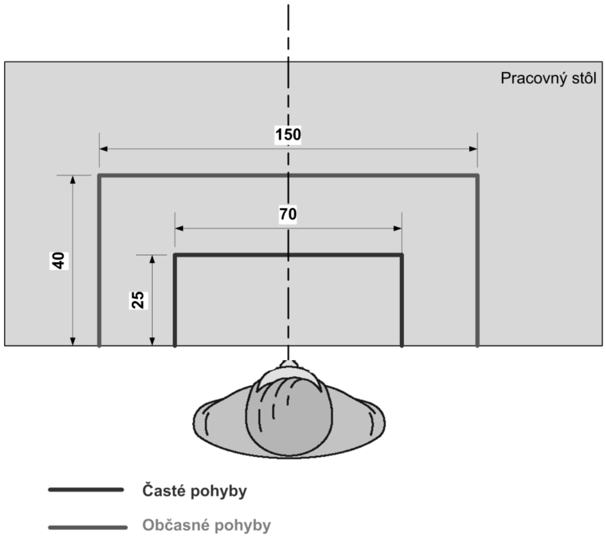
Tab. 4

Rozmery pohybového priestoru horných končatín

Označenie	Rozmer (cm)	
	muži	ženy
Najväčšia kolmá vzdialenosť od roviny MR smerom hore	časté pohyby	
	35	33
	občasné pohyby	
	53	50
	zriedkavé pohyby	
	80	70
Najväčšia kolmá vzdialenosť od roviny MR smerom dole	časté pohyby	
	15	15
	občasné pohyby	
	25	20
Najväčšia kolmá vzdialenosť od zamestnanca smerom dopredu	časté pohyby	
	25	25
	občasné pohyby	
	50	40
Najväčšia kolmá vzdialenosť od zamestnanca smerom doprava (doľava)	časté pohyby	
	40	35
	občasné pohyby	
	75	70

Základné parametre charakterizujúce dosah rúk vo vertikálnej rovine na pracovisku sú **maximálna výška dosahu rúk, minimálna výška dosahu rúk**. Hodnoty týchto parametrov sú pre pracovnú polohu sed odlišné od pracovnej polohy stoj. Hodnoty charakterizujúce jednotlivé orientačné dosahy rúk sú uvedené na obrázku 6.

Pedipulačný priestor je priestor pre nohy, ktorý je určovaný šírkou, výškou a hĺbkou. Mal by vyhovovať pohodlným polohám nôh, ktoré zamestnanec zaujíma v priebehu pracovnej doby. Nedokonalé riešenie pracoviska z tohto hľadiska vedie k statickému zaťaženiu tela a deformácii chrbtice alebo núti zamestnanca pracovať v stoji.



Obr. 6.: Orientačné hodnoty manipulačného priestoru v horizontálnej rovine

Rozmery pohybového priestoru pre nohy sú uvedené v tabuľke číslo 5. Vymedzujú ho vzdialenosti od podlahy a od zamestnanca. Jeho hornú časť ohraničuje spodná plocha pracovnej dosky stola, alebo spodná plocha stolovej časti stroja. Pri zvýšenej manipulačnej rovine, nebudeme merať hodnoty od podlahy ale od hornej plochy opierky nôh v strede podoprených chodidiel. Svojimi rozmermi musí umožňovať dolným končatinám zaujať polohy fyziologicky prípustné a striedať ich. Taktiež obsahuje priestor pre umiestnenie nožných ovládačov.

3.3. Zorný priestor pracoviska

Primárnou požiadavkou väčšiny pracovných úloh sú vizuálne požiadavky. Ak má človek problém vidieť pozorovaný objekt, automaticky sa nakloní dopredu, natiahne krk a prižmuruje oči. Predpokladáme, že tieto činnosti zlepšujú viditeľnosť pozorovaného objektu, pretože sa skráti zorná vzdialenosť a zvýši sa zaostrovacia schopnosť. Problém videnia môže nastať z dôvodu zlých vizuálnych podmienok na pracovisku, alebo z dôvodu osobného poškodenia zraku. Ergonomické projektovanie musí zabezpečiť také podmienky na pracovisku, aby nedochádzalo k poškodzovaniu zraku ani k potrebe nakláňať sa či prižmurovať oči k lepšiemu zaostreniu zraku na pozorovaný objekt. Treba však pri projektovaní brať do úvahy aj fakt, že každý človek na pracovisku má iné vizuálne schopnosti.

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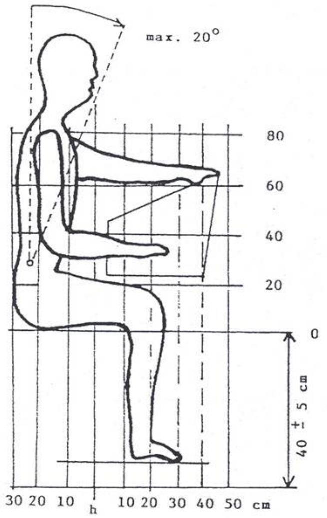

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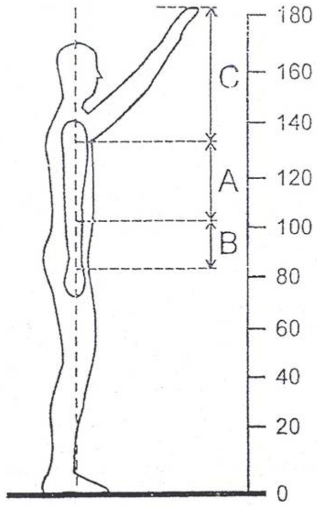


Obr. 7.: Orientačné hodnoty manipulačného priestoru vo vertikálnej rovine

Tab. 5

Rozmery pedipulačného priestoru

Označenie	Rozmer (cm)
najmenšia kolmá výška nad podlahou	60
odporúčaná kolmá vzdialenosť časti pracoviska pod spodnou plochou stola, alebo pod stolovou časťou stroja	70
najmenšia kolmá vzdialenosť časti pracoviska pod spodnou plochou stola, alebo pod stolovou časťou stroja	50
najmenšia šírka od zamestnanca smerom doprava (doľava)	25
minimálna vzdialenosť roviny sedadla od spodnej plochy stola, alebo stolovej časti stroja	20

Pri projektovaní musíme v prvom rade brať do úvahy charakter pracovnej činnosti. Dôležitý je najmenší detail, ktorý pri práci musíme rozlišovať a tomu bude zodpovedať aj zorná vzdialenosť. Optimálna zorná vzdialenosť závisí od veľkosti pozorovaného detailu a od ostrosti zraku. Prehľad pracovných tried podľa zrakovej náročnosti je zobrazený v tabuľke 6.

Tab. 6

Pracovné triedy podľa zrakovej náročnosti

Trieda práce	Zorná vzdialenosť (mm)	Odporúčaná poloha	Charakter činnosti
A	120 – 250	výlučne sed	najjemnejšia práca vykonávaná v sede, s opretými lakťami, kladie veľký dôraz na zrak, montáž najjemnejších súčiastok i s pomocou lupy, prácu môžu vykonávať len ľudia s dobrým zrakom, napr. jemná mechanika, optika, hodinárstvo
B	250 – 350	sed, niekedy stoj	jemné práce v sede i v stoji, montáž drobných súčiastok, práce kresličov, pisárov, ...
C	350 – 500	sed, výhodnejší stoj	menšie nároky na zrakové rozlišovanie detailov, práce v sede i v stoji, väčšina bežných manuálnych prác s náradím a pod.
D	nad 500	stoj, niekedy aj sed	zraková činnosť menej náročná na rozlišovanie a presnosť videnia, balenie, montáž veľkých dielcov, ťažšie a hrubšie ručné práce s náradím a pod.
E	nad 500	výlučne stoj	práca s dlhými pracovnými predmetmi (kladivo, kliešte, a pod.), na pracovnom stole sa nepoužíva podpera horných končatín

Ak má byť pozorovaný objekt dobre videný a rozoznateľný, potom pri normálnej zrakovej ostrosti musí byť:

- určitá úroveň intenzity osvetlenia zorného poľa,
- dostatočný jas objektu alebo plochy, t. j. pomer svietivosti a veľkosti objektu (svietiaceho alebo svetlo odrážajúceho),
- potrebný kontrast objektu vzhľadom k pozadiu,
- dostatočná veľkosť objektu, t.j. čas potrebný na rozoznanie objektu.

Ak nie je niektorá z týchto podmienok splnená tak, aby jej hodnota presahovala minimálnu hranicu, teoreticky nemôže byť videná.

Ak má človek dobre vidieť a rozoznávať, musí byť pri normálnej zrakovej ostrosti:

- umiestnenie predmetu v zornom poli,
- vzdialenosť zdroja informácie osi pohľadu,
- určitá úroveň intenzity osvetlenia,
- potrebný kontrast predmetu vzhľadom k pozadiu,
- doba pozorovania objektu (čas nutný k rozoznaniu).

Pri rozmerovom projektovaní s ohľadom na vizuálne podmienky práce sa berú do úvahy 4 hlavné faktory:

- zorná vzdialenosť,
- zorný uhol,
- zorný priestor,
- veľkosť sledovaného objektu.

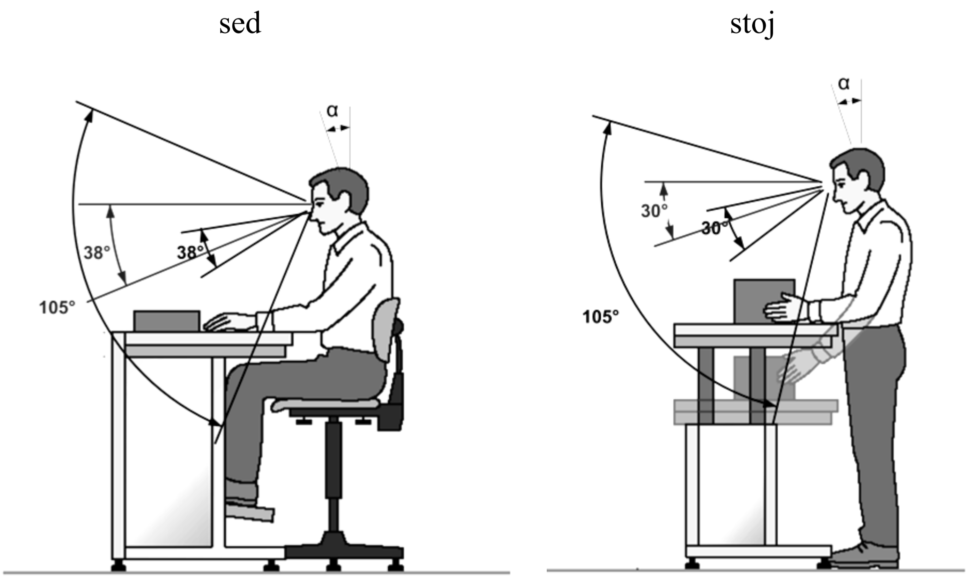
Zorná vzdialenosť – je to vzdialenosť medzi očami a pracovným predmetom, ktorá je potrebná na dodržanie určitej celkovej kontroly pracovného poľa a rešpektuje zásady bezpečnosti práce.

Zorný uhol – je uhol, ktorý zviera horizontálna rovina vedená vo výške oka s priamkou vedenou od oka k pracovnému predmetu.

Zorný priestor – je priestor ohraničený kužeľom vytvoreným uhlom a vzdialenosťou oka od predmetu práce. Zorný priestor považujeme za optimálny zorný priestor, ktorý je vo vertikálnej rovine (obr. 8) tvorený zorným uhlom *38°* pre pracovnú polohu sed a zorným uhlom *30°* pre pracovnú polohu stoj. Maximálny zorný priestor je vo vertikálnej rovine tvorený uhlom *105°* pre obidve pracovné polohy. V závislosti od uhla sklonu hlavy α, ktorý je maximálne *20°*, sa posúva aj zorný uhol. Uhol, ktorý je na obrázku posunutý pod zorným uhlom zamestnanca, je vychýlený práve o uhol sklonu hlavy α. (Zorný uhol na obr. 8 pri sklone hlavy $\alpha = 0°$ je znázornený červenou farbou, uhol pri sklone hlavy $\alpha = 20°$ je znázornený čiernou farbou.)

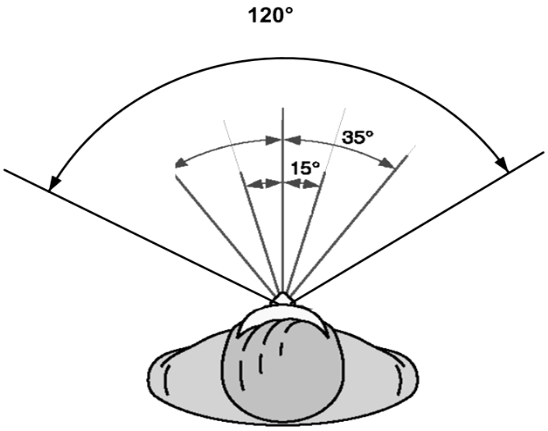
Na základe zorných uhlov rozlišujeme v horizontálnej rovine tri zorné polia:

A optimálne zorné pole je dané uhlom 30°. Zamestnanec vidí objekty v tomto zornom poli bez toho, aby musel otáčať hlavou. V optimálnom zornom poli je videnie ostré.
B normálne zorné pole je dané uhlom 70°. V normálnom zornom poli je videnie dobré.
C maximálne zorné pole je dané uhlom 120°. Predmety ešte môžu byť identifikované bez pohybu hlavy. Videnie v tomto zornom poli je už medzné.



Obr. 8.: Uhly zorného poľa vo vertikálnej rovine pre pracovnú polohu sed a stoj **Chyba! Nenašiel sa žiaden zdroj odkazov.**

Na (obr. 9) je zobrazený zorný priestor v horizontálnej rovine. Uhly zorného priestoru sú rovnaké pre pracovnú polohu sed aj stoj.



Obr. 9.: Uhly zorného poľa v horizontálnej rovine pre pracovnú polohu sed a stoj

Pri projektovaní pracovísk sa zohľadňujú nasledovné požiadavky na zorné pole zamestnanca:

- obmedziť zbytočné pohyby hlavy a očí pri práci, čo má vplyv na opätovné zaostrovanie zraku a namáhanie očí,
- umiestniť často používané pracovné predmety v optimálnom zornom poli A (objekty môžu byť ľahko identifikované pohybom očí bez potreby pohnúť hlavou),
- ak je to možné, neumiestňovať pracovné náradie mimo maximálneho zorného poľa C (objekty môžu byť identifikované bez pohybu hlavy),
- umiestniť zásobníky v rovnakej vzdialenosti, oči zamestnanca tak nemusia zakaždým zaostrovať rozdielnu vzdialenosť, mení sa len uhol pohľadu.

4. Navrhnutie optimálneho usporiadania pracoviska

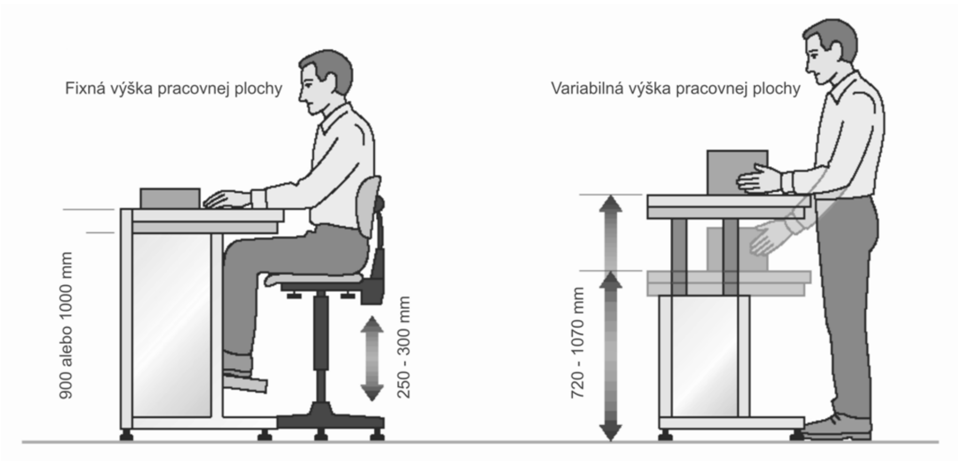
Pracovisko, rôzne pracovné predmety v ňom, ako i pracovné prostriedky musia byť priestorovo usporiadané tak, aby fyzická námaha pri manipulácii s nimi bola čo najmenšia a aby efekt z ľudskej práce bol čo najväčší.

Všetky komponenty, nástroje a príslušenstvo pracoviska majú byť umiestnené v manipulačnom priestore zamestnanca. Ak sú montážne komponenty v manipulačnom priestore ľahko prístupné, zabráni sa otáčaniu tela zamestnanca, naťahovaniu rúk, ohýbaniu a otáčaniu kĺbov zápästia pri uchytení a vyberaní dielcov zo zásobníka, čo redukuje namáhanie a prípadné poranenie, ktoré môže byť vyvolané v dôsledku jednostranných a opakujúcich sa pohybov.

Pri rozmerovom riešení pracoviska musíme vo väčšine prípadov počítať s tým, že ho budú využívať rozmerovo i silovo rozdielni zamestnanci. V praxi sa pri návrhu pracoviska a pracovných zariadení využívajú rozmery muža priemernej postavy, čo nevyhovuje menším postavám (mužov, žien) alebo vyšším postavám.

Na pracovisku, kde budú striedavo pracovať muži a ženy, je potrebné prednostne rešpektovať rozmerové, tvarové, fyziologické a funkčné odlišnosti ženskej postavy.

Výška pracovnej plochy by však mala vyhovovať zamestnancom s rôznymi telesnými rozmermi. Možným riešením daného problému sú stavebnicové pracoviská, ktoré umožňujú variantné prispôsobenie pre výškovú škálu zahrňujúcu 95 % rozmerov dospelých mužov a žien (obr. 10).



Obr. 10.: Optimálna výška pracovných stolov pre prácu v sede a stoji

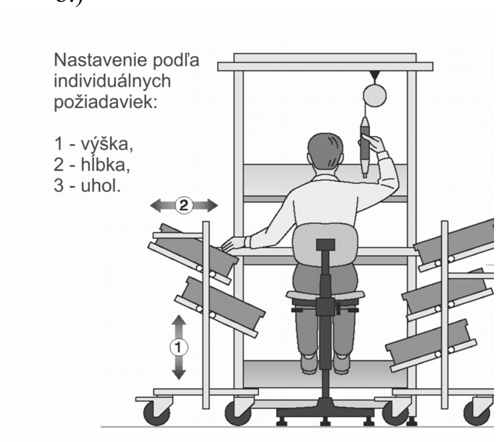
Ak je technicky možné, aby pracovisko bolo v niektorých rozmeroch flexibilné (napr. ak je požadovaná nastaviteľná výška sedadla, výškové prispôsobenie pracovnej plochy alebo podložky), je možné vytvoriť optimálne priestorové podmienky pre najširší okruh zamestnancov.

Pracovný stôl, stolička, opierka nôh, zásobníky, držiaky nástrojov, zásobníkové vozíky a pod. majú byť prispôsobené telesným rozmerom zamestnancov a ich pracovným úlohám. Správne nastavené pracovné pomôcky redukujú namáhanie a časové prestoje a súčasne zvyšujú produktivitu a výkonnosť. Vyžaduje sa:

- umiestniť komponenty a nástroje do správnej výšky a vzdialenosti;
- vybrať k pracovnému stolu vhodnú stoličku a umiestniť opierku nôh (obr. 11a);
- umiestniť manipulačný vozík so zásobníkmi materiálu v dosahovom priestore a v takom uhle, aby sa zlepšila prístupnosť rúk k súčiastkam (obr. 11b).

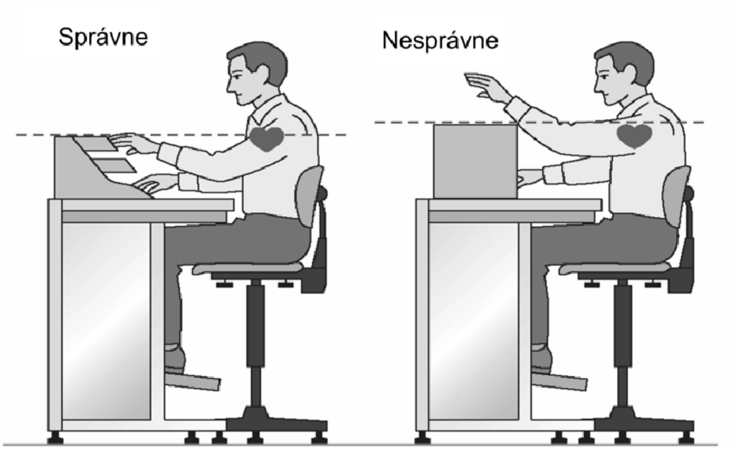
a.)

b.)



Obr. č. 11 a) Upravenie pracovnej pozície v sede b) nastavenie zásobníkov manipulačného vozíka

Pri riešení rozmiestnenia pracoviska je potrebné zabrániť umiestneniu vybavenia pracoviska nad výškou srdca zamestnanca, pretože môže dôjsť k redukcii cirkulácie krvi, z ktorej vyplýva pokles výkonnosti zamestnanca (obr. 12).

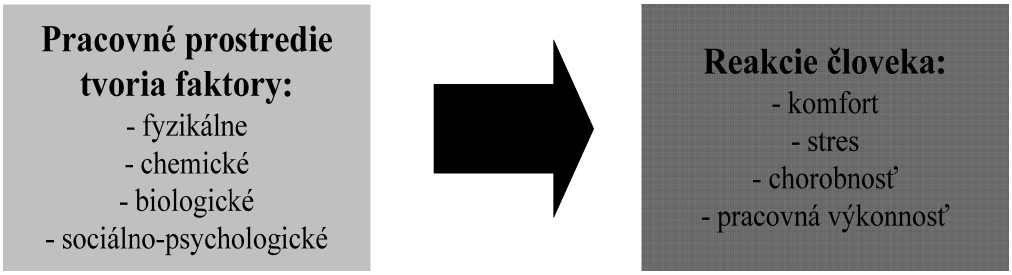


Obr. 12.: Vhodné a nevhodné rozmiestnenie komponentov na pracovisku pod úrovňou výšky srdca zamestnanca

Ovládacie prvky, náradie, nástroje, výrobné pomôcky a zásobníky majú byť uložené tak, aby umožňovali človeku účinné pracovné pohyby. V priestore pracoviska nesmú byť žiadne prekážky, ktoré by zaťažovali vykonávanie pracovných pohybov alebo zbytočne predlžovali dráhu pohybu. Tvarové usporiadanie pracoviska musí umožňovať pohodlnú vizuálnu kontrolu všetkých informačných zdrojov a sledovanie výrobného procesu.

5. Návrh prvkov ovplyvňujúcich mikroklimatické podmienky na pracovisku a podmienky pracovného

Pracovné prostredie je definované ako súbor podmienok, v ktorých sa vykonáva práca. Pracovné podmienky sú fyzikálne, chemické, biologické, psychologické a sociologické faktory, ktoré pôsobia na zdravie a pracovnú výkonnosť človeka v pracovnom procese. Pracovné podmienky sú ovplyvňované režimom práce, odpočinkom ako aj technickým vybavením pracovného prostredia. O zdravých životných a pracovných podmienkach sa dá hovoriť vtedy, ak nepôsobia nepriaznivo na zdravie ľudí, ale naopak ho chránia a kladne ovplyvňujú. Prostredie pôsobí na človeka svojimi fyzikálnymi, chemickými, biologickými a sociálno-psychologickými faktormi. Tieto faktory komplexne pôsobia na nervovú sústavu a psychiku človeka, ovplyvňujú jeho výkon a limitujú celkové podmienky práce. Interakcie pracovného prostredia a človeka sú zobrazené na obr. 13.



Obr. 13.: Interakcie pracovného prostredia a človeka

Vytvorenie optimálnych pracovných podmienok, zohľadniť všetky tieto faktory a dbať na to, aby navrhnuté prostredie bolo čo najmenej zdraviu škodlivé, je neoddeliteľnou súčasťou projektovej prípravy výroby, a to nielen pri nových stavbách, ale aj pri rekonštrukciách existujúcich priemyselných prevádzok. V praxi sa ukazuje, že nie je docenený význam kvality pracovného prostredia, nie sú dodržiavané technické normy, hygienické požiadavky, ergonomické parametre a pod. Významný podiel zodpovednosti za pracovné prostredie pripadá okrem projektantov aj investorovi a prevádzkovateľovi organizácie.

6. Navrhnutie oznamovačov a bezpečnostných prvkov pracoviska

6.1. Navrhovanie oznamovačov

V zložitých pracovno-organizačných systémoch musí človek reagovať na určitý signál veľmi rýchlo, aspoň tak, aby pracovná činnosť prebiehala v optimálnom tempe. Preto treba zistiť, akú má signál kvalitu, intenzitu, rozmery a dobu trvania, aby zamestnanec mohol reagovať čo najrýchlejšie a najpresnejšie. Ide najmä o problematiku určenia reakčných časov.

Rýchlosť reakcie alebo odpovede zamestnanca závisí nielen od charakteru podnetu, ale aj od vonkajšieho okolia, t. j. celkovej zložitosti situácie. Preto systém človek - stroj treba aj z hľadiska oznamovacích zariadení sledovať komplexne. Druhou podmienkou, ktorá vplýva na rýchlosť a presnosť reakcie človeka, je totiž stav zmyslových orgánov a celkovej nervovej sústavy zamestnanca.

6.2. Navrhovanie displejov

Displeje sú zariadenia, ktoré informujú zamestnanca o priebehu a stave výroby, stave sledovaných parametrov, chode stroja a technológie práce. Rozširujú oblasť vnímania zamestnanca o údaje, ktoré by buď z technických alebo psychologických dôvodov inak unikli jeho pozornosti, ale sú pre chod zariadenia dôležité. Prvoradou požiadavkou na všetky druhy displejov je podanie zrozumiteľných, presných a rýchlych informácií. Displeje uvádzajú informácie, ktoré sa môžu meniť tak, aby boli tieto informácie viditeľné, počuteľné alebo rozlíšiteľné na dotyk.

Displeje sa musia voliť, konštruovať a usporiadať tak, aby zodpovedali možnostiam ľudského vnímania. Musia vyhovovať požiadavke na jasné, rýchle a spoľahlivé rozlíšenie poskytovaných informácií a rozpoznanie ich významu.

6.3. Bezpečnostné prvky

V organizačnej štruktúre každej organizácie je zodpovedné za riadenie bezpečnosti a ochrany zdravia pri práci vedenie spoločnosti (top manažment). Povinnosti, zodpovednosť a právomoci sú ďalej definované organizačnou štruktúrou s poverením konkrétnych osôb v oblasti starostlivosti o BOZP, kde tieto úlohy sú povinný zabezpečovať vedúci zamestnanci na všetkých stupňoch riadenia v rozsahu úloh vyplývajúcich z ich funkcií. Tieto úlohy sú rovnocennou a neoddeliteľnou súčasťou ich pracovných povinností.

Základné interné riadiace dokumenty sú vydávané napríklad formou príkazov či rozhodnutí generálneho riaditeľa, kde sú určené konkrétne termíny a zodpovednosti za prijaté opatrenia v oblasti BOZP. Spôsob zabezpečovania základných úloh organizácie je rozpracovaný v organizačných predpisoch spoločnosti. V nich je konkrétne uvedená zodpovednosť a spôsob zabezpečenia týchto úloh.

Úlohy bezpečnostnotechnickej služby u zamestnávateľa vykonáva bezpečnostný technik a autorizovaný bezpečnostný technik a podľa potreby aj iný odborník na prevenciu a ochranu v špecifickej oblasti bezpečnosti a ochrany zdravia pri práci.

6.4. Estetické riešenie pracovného priestoru

Dôležitou súčasťou optického prostredia je farebná úprava pracovného prostredia a pracoviska.

Farebné riešenie pracovísk má spĺňať nasledovné požiadavky:

- celkové farebné ladenie má byť harmonické, príjemné zraku,
- výber farebných odtieňov sa riadi hlavne účelnosťou a všeobecnou estetickou pôsobivosťou.

Využívajú sa predovšetkým jemné farebné odtiene, menej sýte farby tlmené bielou alebo svetlo šedou farbou.

Živé sýte farby sa využívajú tam, kde je to nutné z funkčných dôvodov (upozornenie na nebezpečné miesta a predmety, označenie únikových východov, požiarnych zariadení).

Každá farba má psychologický a vizuálny účinok na človeka a jej uplatnenie musí mať spojitosť s ostatnými podmienkami prostredia.

Pri voľbe farebných odtieňov (stien, stropu, konštrukcií a pod.) je nutné zvážiť tieto okolnosti: druh prevládajúcej činnosti, veľkosť a tvar priestoru, farbu spracovávaných predmetov, farbu a intenzitu osvetlenia a mikroklimatické podmienky. Farebné riešenie strojov a technických zariadení musí zodpovedať bezpečnostnému významu farieb. Pri návrhu farebného riešenia pracovného priestoru je potrebné, aby sa brali do úvahy nasledovné vplyvné faktory:

1. Povaha a trvanie činnosti vykonávanej na pracovisku.

   Je potrebné zohľadniť, či ide o prácu fyzickú, duševnú, monotónnu, namáhajúcu zrak a pod. Pre konkrétne situácie platia nasledovné zásady:

- v pracovnom priestore pri práci v sede s malým fyzickým zaťažením sa odporúčajú teplé farby,
- pri práci v stoji a pri chôdzi sa steny a strop odporúčajú farbiť ľahkými tónmi studených farieb,
- pracovný priestor pre práce vyžadujúce si koncentráciu pozornosti sa vyžadujú odtiene zelenej a modrej farby,
- pre monotónnu prácu sa odporúča kombinácia teplých farieb s bielou farbou,
- v kancelárskych priestoroch sú vhodné harmonické farby: žltá, žltozelená, žltohnedá, svetlohnedá,
- priestory pre vedúcich pracovníkov je potrebné farebne riešiť tak, aby boli vhodné na vysoké sústredenie a zároveň v sebe zahŕňali reprezentatívnosť a individualitu pracovníka.
- tvar a veľkosť priestoru:
- úzky a dlhý priestor sa dá opticky rozšíriť ak sa na kratšie steny použije sýty odtieň pestrej farby a na dlhšie steny jemný odtieň svetlej farby,
- nízky priestor sa dá zvýšiť použitím svetlého odtieňu na strope,
- významné prvky na pracovisku by mali byť zvýraznené sýtymi odtieňmi pastelových farieb a bezvýznamné prvky by mali byť potlačené použitím jemných odtieňov svetlých farieb.

2. Teplota na pracovisku.

   Vhodným použitím farieb je možné psychologicky zmierniť nevhodné teplotné pomery na pracovisku:

- v studených priestoroch sa používajú teplé farby,
- v teplých prevádzkach sa používajú studené farby.

3. Intenzita osvetlenia.

   Vhodným farebným riešením sa dajú čiastočne riešiť problémy s nie práve najvhodnejším osvetlením. V takomto prípade sa volia farby podľa ich schopností odrážať svetlo:

- v málo osvetlených priestoroch sa odporúča biela farba,

- v presvetlených priestoroch sa používajú odtiene žltej alebo žltohnedej farby a odtiene modrej a zelenej farby.

4. Zloženie pracovníkov podľa veku a pohlavia:

- pre starších pracovníkov alebo prevažne mužov sa odporúčajú svetlé odtiene studených farieb,
- pre mladších pracovníkov alebo prevažne ženy sa odporúčajú pestré pastelové farby.

V praxi nie je možné zohľadniť všetky uvedené faktory súčasne. Podľa priorít konkrétneho pracoviska je potrebné citlivo zvoliť tie faktory, ktoré môžu najviac vplývať na pracovný proces.

Tab. 7

Prehľad aktivít moderného ergonomického projektovania pracovísk

Plánovaná aktivita	Vstupné informácie	Výstupné informácie - pôvodné	Výstupné informácie
Analýza pracovného priestoru	Rozmerové parametre celého priestoru	Technická dokumentácia stavby	Ergonomická analýza pracovného priestoru z pohľadu plošného a priestorového
Tvorba priestorových štandardov	Ergonomická analýza pracovného priestoru z pohľadu plošného, priestorového a fyzikálnych vlastností prostredia	Technická dokumentácia stavby s ergonomickou analýzou	Vytvorenie priestorových štandardov pre pracoviská
Kapacitné plánovanie pracoviska	Priestorových štandardy pre pracoviská	Dokumentácia k priestorovým štandardom	Kapacitné prepočty pre rozmiestnenie strojov, pracovísk a zamestnancov. Komplexné údaje pre tvorbu 3D modelu pracovného priestoru.

Tab. 7 (pokračovanie)
Prehľad aktivít moderného ergonomického projektovania pracovísk

Plánovaná aktivita	Vstupné informácie	Výstupné informácie - pôvodné	Výstupné informácie
Určenie základných rozmerov i-teho pracoviska	Druh pracovnej činnosti, počet operátorov, pracovné polohy, technické vybavenie, špeciálne požiadavky	Technologické postupy, konštrukčné riešenie pracoviska, technická dokumentácia k strojom	Základné rozmery i-teho pracoviska
Určenie dosahových zón i-teho pracoviska	Charakteristiky operátorov, antropometrické údaje	Antropometrický atlas, Ergo softvér pre projektovanie pracovísk	Komplexné údaje pre tvorbu 3D modelu pracoviska i-teho
Navrhnutie optimálneho usporiadania na pracovisku	Jednotlivé druhy manipulačných jednotiek, nástrojov, pracovných predmetov, pomocného materiálu a pod.	Technologická a konštrukčná dokumentácia výroby. Technické parametre od dodávateľov manipulačných jednotiek	Komplexné údaje pre tvorbu 3D modelu pracovného postupu. Vstupné údaje pre záťažové analýzy.
Návrhy riešenia fyzikálnych parametrov pracovného prostredia - svetlo	Namerané hodnoty osvetlenia	Platná legislatíva, výsledky meraní	Návrh zdrojov umelého osvetlenia pracovísk. Vypracovanie mapy osvetlenia
Návrhy riešenia fyzikálnych parametrov pracovného prostredia – hluk, vibrácie	Namerané hodnoty hluku a vibrácií	Platná legislatíva, výsledky meraní	Návrh protihlukových a protivibračných opatrení. Vypracovanie mapy hluku
Návrhy riešenia fyzikálnych parametrov pracovného prostredia - mikroklíma	Namerané hodnoty mikroklimatických charakteristík (teplota, vlhkosť, prúdenie vzduchu)	Platná legislatíva, výsledky meraní	Návrh opatrení pre optimalizáciu mikroklímy, ohrievače, klimatizácie, zvlhčovače a pod.

Tab. 7 (pokračovanie)

Prehľad aktivít moderného ergonomického projektovania pracovísk

Plánovaná aktivita	Vstupné informácie	Výstupné informácie - pôvodné	Výstupné informácie
Návrhy riešenia fyzikálnych parametrov pracovného prostredia - mikroklíma	Namerané hodnoty mikroklimatických charakteristík (teplota, vlhkosť, prúdenie vzduchu)	Platná legislatíva, výsledky meraní	Návrh opatrení pre optimalizáciu mikroklímy, ohrievače, klimatizačné jednotky, zvlhčovače a pod.
Návrhy riešenia fyzikálno - chemických parametrov pracovného prostredia.	Namerané hodnoty obsahu škodlivín v ovzduší, intenzity žiarení a pod.	Platná legislatíva, výsledky meraní	Návrh opatrení pre optimalizáciu fyzikálno - chemických parametrov prostredia.
Návrh oznamovačov	Parametre výroby, vizualizačné údaje z oblasti výrobného manažmentu, údržby, 5S, technologické obmedzenia, BOZP a pod.	Informačný systém, odd. priemyselného inžinierstva, BOZP	Návrh obsahového a priestorového riešenia oznamovačov na pracoviskách
Návrh displejov	Informácie rozpracovanosti výroby, plánu výroby, 3D vizualizácie pracovných postupov, vizualizácia BOZP	Informačný systém, odd. priemyselného inžinierstva	Návrh obsahového a priestorového riešenia displejov na pracoviskách
Návrh bezpečnostných prvkov	Zoznam bezpečnostných rizík na pracovisku	BOZP, Integrovaný manažérsky systém	Návrh bezpečnostných prvkov na pracoviskách
Estetické riešenie pracovísk	Farebné štandardy podniku, materiály 5S, ergonomické štandardy pre pracovnú pohodu	Materiály odd. priemyselného inžinierstva, farebné riešenia v rámci BOZP	Návrh estetického riešenia pracovísk

Chapter 1.4.

PODEJMOWANIE DECYZJI PRODUKCYJNYCH WSPOMAGANE TECHNIKAMI SYMULACYJNYMI ORAZ LOGIKĄ ROZMYTĄ

SUPPORT FOR DECISION-MAKING PROCESSES IN MANUFACTURING UTILIZING SIMULATION/MODELING TECHNIQUES AND FUZZY LOGIC

Sławomir KUKLA[1]

Słowa kluczowe: doskonalenie systemów produkcyjnych, techniki symulacyjne

Streszczenie
W pracy przedstawiono możliwość wykorzystania techniki modelowania i symulacji systemów produkcyjnych w zarządzaniu procesami wytwórczymi. W ramach pracy przeprowadzono analizę usprawnień systemu produkcyjnego przykładowego przedsiębiorstwa przemysłu meblowego. Zastosowano narzędzia oceny wielokryterialnej wariantów, w których do oceny kryteriów oraz wariantów rozwiązań wykorzystano subiektywne oceny punktowe oraz oceny o charakterze rozmytym.

[1] Akademia Techniczno-Humanistyczna w Bielsku-Białej
Katedra Inżynierii Produkcji
skukla@ath.bielsko.pl

1. Wprowadzenie

W dobie globalizacji coraz większe wymagania, dotyczące jakości produkcji oraz obniżenia kosztów wprowadzania nowych technologii, wymuszają na przedsiębiorstwach konieczność stosowania bardziej zaawansowanych narzędzi pozwalających na wirtualne planowanie i analizowanie zadań produkcyjnych.

Odpowiednio zaprojektowane procesy wytwórcze wymagają, połączenia we właściwych proporcjach, w czasie i przestrzeni procesów podstawowych i pomocniczych, przygotowania produkcji i sterowania, a także racjonalnej organizacji zapewniającej ciągłość produkcji poprzez eliminowanie wszelkiego rodzaju zakłóceń. Do zadań racjonalizacji i optymalizacji procesów produkcyjnych należy podchodzić indywidualnie. Przedsiębiorstwa, które chcą odnosić sukcesy w swojej branży, pozyskiwać nowych klientów, zwiększać asortyment i efektywność produkcji zmuszone są do stosowania systemów komputerowych wspomagających zarządzanie działaniami produkcyjnymi.

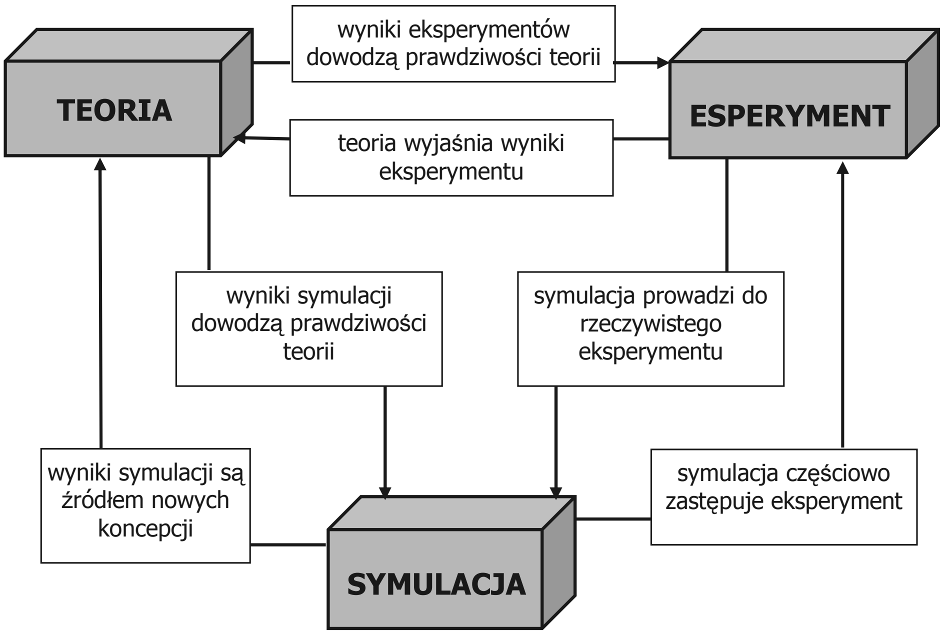
Konieczność skracania czasu przygotowania produkcji wymusza stosowne działania mające na celu automatyzację poszczególnych faz rozwoju produktu poprzez ich komputerową integrację w oparciu o modele produktów, modele procesów i środków produkcji oraz w powiązaniu z problemowo i procesowo zorientowanymi bazami danych.

Większy zysk przedsiębiorstwo może uzyskać oferując klientom wyroby o bardzo wysokiej jakości i z doskonałym serwisem oraz systematycznie zmniejszając ponoszone koszty i skracając czas realizacji zleceń. Konieczne jest więc nowe spojrzenie na problem szacowania i rozliczania kosztów. Przedsiębiorstwa zmuszone są do manipulowania kosztami, a nie ceną jak to miało miejsce w przeszłości. W dzisiejszych czasach cena jest wartością wynikającą z relacji na rynku konsumenta. Zysk, mający wpływ na funkcjonowanie i rozwój przedsiębiorstwa, nie może być mniejszy od pewnej granicznej wartości. W związku z tym nowoczesny producent może manipulować jedynie kosztami produkcji, na które ma on bezpośredni wpływ.

2. Techniki symulacyjne w zarządzaniu produkcją

Badania teoretyczne prowadzone na modelach dostarczają istotnych informacji, umożliwiając dokonanie szerokiej oceny jakościowej i ilościowej występujących zjawisk. Niewątpliwie warto zwrócić, zatem uwagę na sferę zadań, jaką obejmuję symulacja, i jej wpływ na osiągany wynik ekonomiczny firm.

Zebrane w trakcie symulacji komputerowych informacje pozwalają poznać badane zjawiska z pominięciem budowania rzeczywistych systemów i przeprowadzania kosztownych eksperymentów (rys. 1). Z kolei wiedza zdobyta na etapie modelowania może być uwzględniona podczas budowania instalacji przemysłowych.



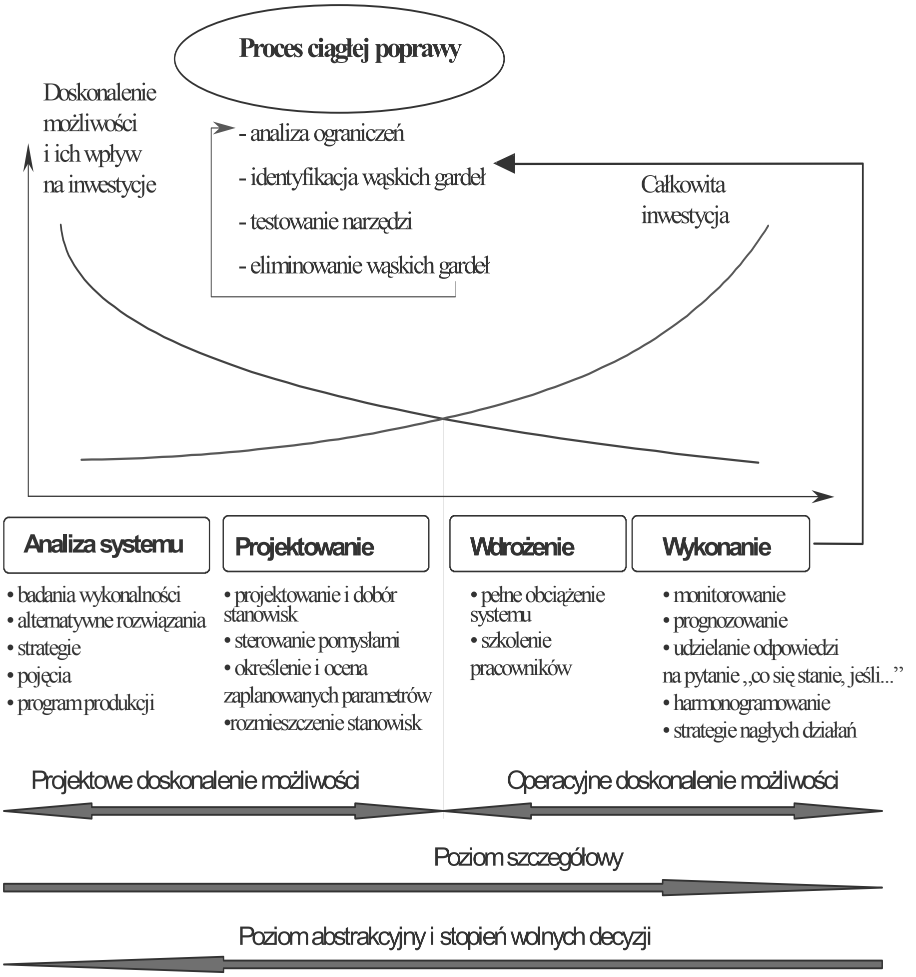
Rys. 1.: Powiązanie między teorią, symulacją i eksperymentem

Modelowanie i symulacja procesów wytwórczych umożliwia ich ocenę oraz daje szansę przeanalizowania funkcjonowania wybranych obiektów (stanowisk roboczych, operacji technologicznych, zabiegów, czynności, operacji transportowych, stanów magazynowych, zakłóceń itp.). Pozwala przeprowadzić weryfikację przyjętych założeń przed ich zastosowaniem w praktyce, a także określić nieprawidłowości, jakie mogą wystąpić w czasie eksploatacji, w tym szczególnie słabe punkty projektowanego lub realizowanego systemu produkcyjnego. Metody modelowania i symulacji stosuje się wtedy, gdy uzyskanie rozwiązania metodami analitycznymi jest zbyt skomplikowane lub niemożliwe, a bezpośrednie eksperymentowanie na rzeczywistym systemie jest zbyt pracochłonne, niebezpieczne i kosztowne. Modelowanie procesów wytwórczych sprowadza się do określenia charakterystyki i zachowania poszczególnych elementów procesu oraz relacji zachodzących między nimi. Proces wytwórczy może być przedstawiony jako zbiór dynamicznych systemów składających się z szeregu niezwiązanych lub współpracujących z sobą procesów, gdzie każdy proces zdefiniowany jest jako ciąg działań (3).

Charakteryzując zakres zastosowań modeli symulacyjnych, można wymienić następujące zadania, jakie najczęściej są stawiane przy ich tworzeniu:

- sprecyzowanie opisu procesu, który może być w dalszej kolejności uściślany o nowe informacje oraz wskazywanie na pewne właściwości procesu, których zbadanie na realnym procesie jest utrudnione lub niemożliwe,
- wykorzystanie modelu symulacyjnego do badań efektywności struktur zarządzania czy też sterowania, co powinno doprowadzić do wyboru najwłaściwszych struktur i algorytmów podejmowania decyzji,
- zastosowanie modeli w systemach sterowania złożonymi procesami, współudział w zarządzaniu, systemami technologicznymi, ekonomicznymi, administracyjnymi.

Symulacja jest bardzo dobrym narzędziem wspomagającym podejmowanie decyzji na różnych poziomach zarządzania przedsiębiorstwem (rys. 2). Dzięki zastosowaniu tej techniki można przeprowadzać eksperymenty na złożonym systemie przed rozpoczęciem realizacji projektu w praktyce. W ciągu kilku minut można prześledzić przebieg złożonych procesów produkcyjnych, które w rzeczywistości trwają kilka dni, tygodni czy nawet miesięcy. Symulacja pozwala na zobrazowanie zachowania się systemu po wdrożeniu planowanych zmian i na wyłapanie ewentualnych problemów mogących wystąpić w przyszłości. Projekt symulacyjny nie stwarza możliwości znalezienia optymalnego rozwiązania, ale jest narzędziem wspomagającym pracę projektanta i umożliwiającym wybranie wariantu najlepiej spełniającego założone kryteria. Wiarygodność decyzji, opartych na badaniach symulacyjnych, ogranicza się do uprzednio sprawdzonych wariantów.



Rys. 2.: Wykorzystanie techniki symulacyjnej w różnych etapach przebiegu racjonalizacji systemu produkcyjnego

Na etapie planowania produkcji symulacja może być wykorzystana zarówno do określania przepustowości wybranych stanowisk produkcyjnych, jak i szacowania sprawności i wydajności całych linii wytwórczych. Zbudowany model może być użyty do określenia różnych algorytmów kontroli projektowanego systemu wytwarzania. Ponadto modele symulacyjne mogą służyć jako pomoce dydaktyczne w szkoleniach personelu mogących odbywać się już w trakcie budowy konkretnego systemu produkcyjnego.

Głównymi obszarami zastosowania modelowania i symulacji systemów produkcyjnych są:

- projektowanie systemów produkcyjnych,
- porównywanie alternatywnych procesów wytwarzania,
- planowanie i sterowanie produkcją,
- analiza wykorzystania dostępnych zasobów produkcyjnych (wykrywanie tzw. wąskich gardeł),
- analiza efektywności zamierzonych inwestycji,
- prognozowanie i planowanie zamówień,
- ciągłe doskonalenie procesów i usuwanie marnotrawstwa (KAIZEN),
- przeprowadzanie prezentacji i szkoleń dla personelu,
- prognozowanie wyników finansowych przedsiębiorstwa.

Aby uzyskać możliwie wysokie korzyści z zastosowania techniki symulacyjnej, to musi być ona przeprowadzona w odpowiednim etapie realizacji procesu. Największe możliwości poprawy parametrów systemu uzyskuje się w pierwszej fazie projektu na etapie analizy i projektowania. W późniejszym czasie realizacji projektu pozostaje mniej swobody na dokonywanie zmian, a przy ich realizacji pojawiają się dodatkowe koszty, które mogą spowodować, iż poniesione koszty przewyższą przyszłe zyski uzyskane dzięki przeprowadzonej racjonalizacji systemu (2, 8).

Do głównych zalet symulacji komputerowej, w porównaniu z innymi metodami analizy procesów, można zaliczyć:

- elastyczność modelu rozumiana jako łatwość wprowadzania zmian w modelu symulowanego procesu oraz łatwość uzupełniania go o nowe zjawiska,
- łatwość wprowadzania różnego rodzaju wymuszeń i zakłóceń, w szczególności o charakterze losowym (np. awarie),
- stosunkowo niewielki koszt i czas przygotowania oraz przeprowadzania symulacji w porównaniu z przeprowadzaniem eksperymentów na systemie rzeczywistym,
- wiarygodność wyników symulacji, zwłaszcza w przypadku możliwości porównania wyników symulacji z danymi otrzymanymi z pomiarów na rzeczywistym systemie,

- zwalnianie i przyśpieszanie przebiegu symulacji pozwalające na dokładne prześledzenie zjawisk pojawiających się w badanym systemie,
- rozpoznawanie ograniczeń umożliwiające usunięcie skutków opóźnień w procesie wytwórczym, przepływie informacji itp.,
- możliwość wizualizacji planu zakładu oraz przebiegów procesów dla celów szkoleniowych,
- możliwość symulacji funkcjonowania systemu w warunkach ekstremalnych.

3. Proces decyzyjny wspomagany logiką rozmytą

Głównym celem wprowadzenia pojęcia zbiorów rozmytych była potrzeba matematycznego opisania tych zjawisk i pojęć, które maja charakter wieloznaczny i niedokładny. Na systemy rozmyte składają się te techniki i metody, które służą do przedstawiania informacji nieprecyzyjnych, nieokreślonych bądź niekonkretnych. Charakteryzują się tym, iż wiedza przetwarzana jest w postaci symbolicznej i zapisywana w postaci rozmytych reguł. Systemy rozmyte znajdują zastosowanie tam, gdzie nie dysponuje się wystarczającą wiedzą o modelu rządzącym danym zjawiskiem oraz tam gdzie odtworzenie modelu staje się nieopłacalne lub w niektórych przypadkach nawet niemożliwe ze względu na niewystarczającą ilość informacji o charakterze deterministycznym.

Zgodnie z założeniami logiki klasycznej, która stanowi fundament teorii zbiorów rozmytych, element może należeć do zbioru lub do niego nie należeć. Przynależność do zbioru jest, więc zdefiniowana funkcją przyjmującą dwie wartości: 0 lub 1. W odróżnieniu od zbioru klasycznego funkcja przynależności zbioru rozmytego może przyjmować dowolne wartości z przedziału <0, 1>. Taki sposób klasyfikacji jest bardziej zbliżony do ludzkiego procesu myślenia, który jest z natury mglisty. Wprowadzając pewną dozę niedokładności, zyskuje się odporność systemu, która umożliwia modelowanie złożonych procesów (1, 4, 7).

Zgodnie z powyższymi założeniami można zdefiniować zbiór rozmyty przy pomocy równości:

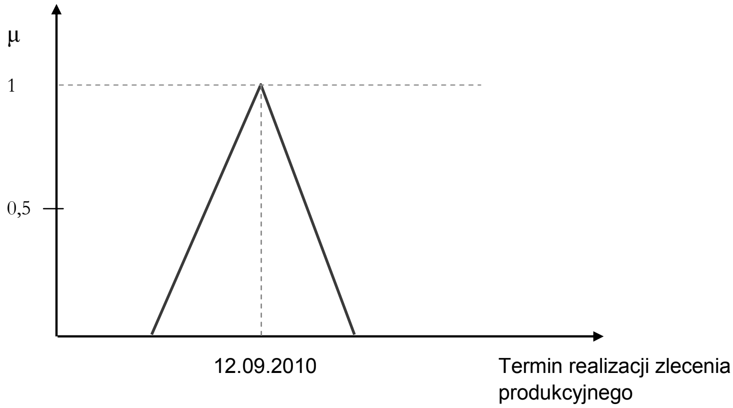
$$A = \{x, \mu_A(x)) : x \in X, \mu_A(x) \in [0,1]\} \quad (1)$$

gdzie:

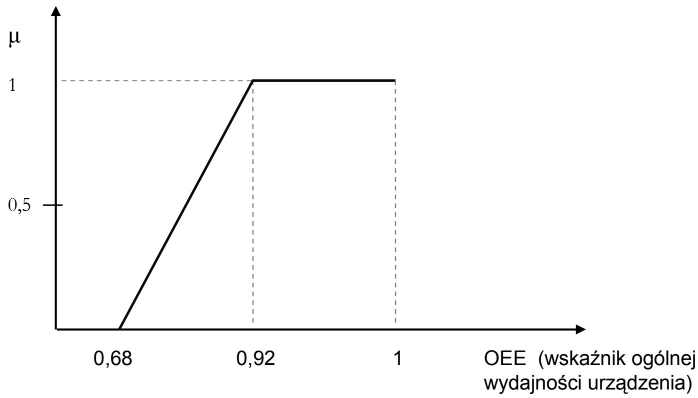
A – zbiór klasyczny,

μ_A – funkcja przynależności zbioru rozmytego.

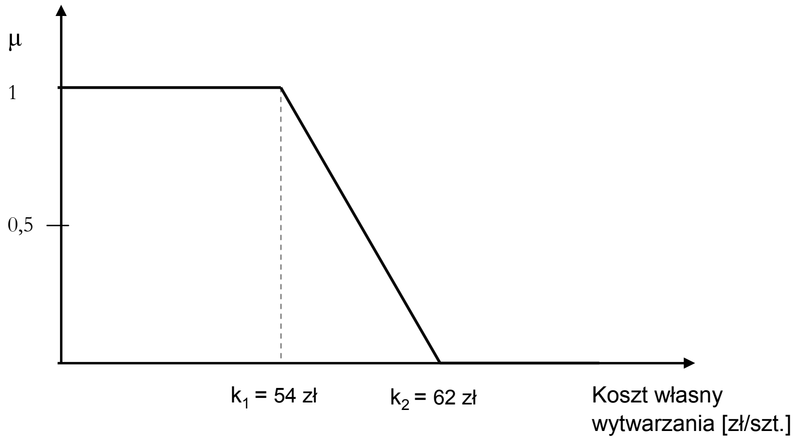
W praktycznych zastosowaniach teorii zbiorów rozmytych często korzysta się z kilku rodzajów funkcji przynależności charakteryzujących zmienne lingwistyczne. Na rysunkach 3, 4, 5 oraz 6 przedstawiono najczęściej stosowane postacie funkcji w rozwiązywaniu zagadnień decyzyjnych z zakresu zarządzania produkcją.



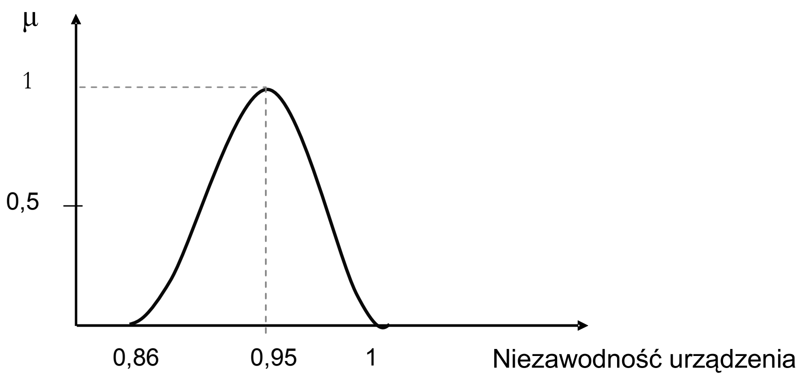
Rys. 3.: Przykład funkcji przynależności klasy Λ



Rys. 4.: Przykład funkcji przynależności klasy Γ



Rys. 5.: Przykład funkcji przynależności klasy L



Rys. 6.: Przykład funkcji przynależności klasy $\prod$

Podstawy wiedzy z zakresu logiki rozmytej znajdują również zastosowanie w modelowaniu i symulacji komputerowej. Podstawą modelowania jest, bowiem teoria prawdopodobieństwa rozpatrywana z punktu widzenia uproszczenia modelu tzn. wyboru niezbędnego i wystarczającego stopnia jego podobieństwa do obiektu modelowanego.

W oparciu o kryteria o charakterze rozmytym można również realizować procesy decyzyjne biorąc pod uwagę wiele kryteriów równocześnie i określając ich ważność (6).

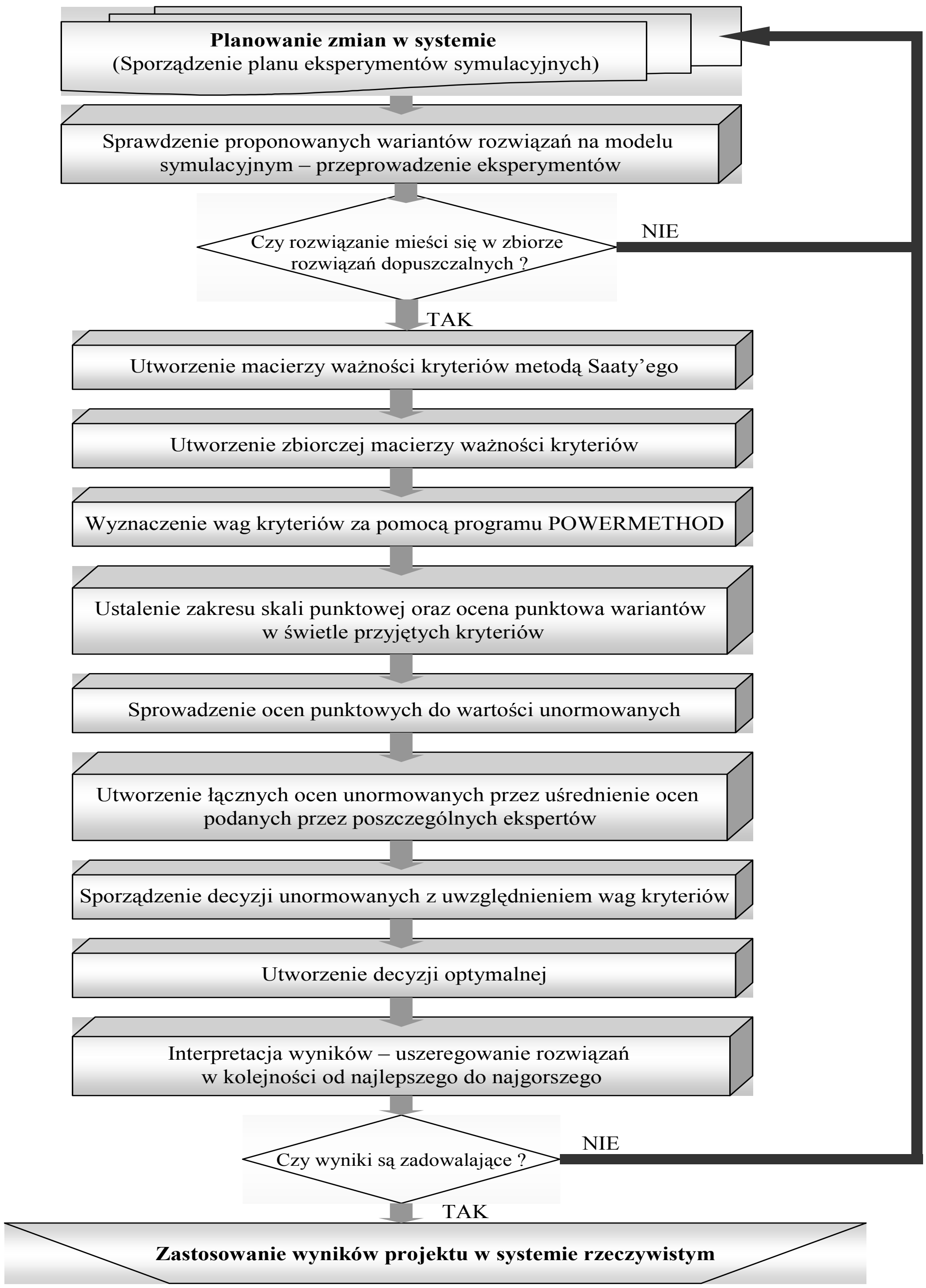
Znanych jest wiele sposobów i metod rozwiązywania zagadnień oceny wielokryterialnej rozwiązań w świetle wielu kryteriów. Jedną z metod oceny i wyboru rozwiązania preferowanego jest metoda Yagera (rys. 7).

Do danych wyjściowych tej metody zalicza się:ň

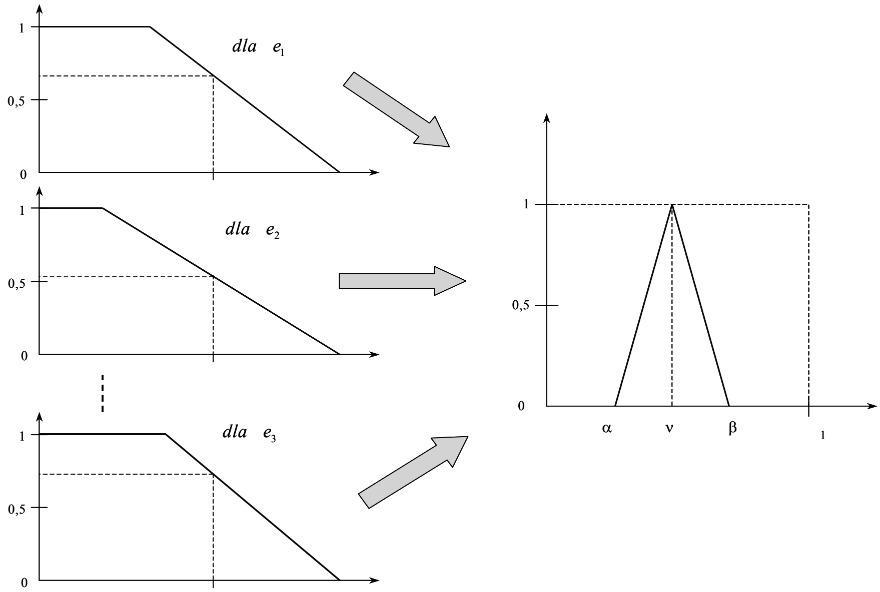
- liczbę kryteriów,
- liczbę wariantów,
- elementy macierzy ważności poszczególnych kryteriów,
- elementy tablicy, które są unormowanymi ocenami punktowymi poszczególnych wariantów według każdego z kryteriów przygotowanymi przez wszystkich decydentów.

Do oceny ważności kryteriów oraz oceny wariantów angażuje się ekspertów (decydentów). Każdy z ekspertów jest odpowiedzialny za zbudowanie macierzy ocen ważności kryteriów metodą Saaty'ego, polegającą na porównywaniu kolejnych par przyjętych kryteriów a w dalszej kolejności ocena wariantów według przyjętych kryteriów. Według innej metody oceny wielokryterialnej rozwiązań ważność kryteriów oraz warianty przebiegu procesu oceniane są parami, a każdej parze przyporządkowuje się ocenę punktową z przyjętego przedziału.

W przypadku wielkości deterministycznych oceny cząstkowe wariantów określane są w zależności od kryterium i przyjętej skali wartości (np. koszt w zł). Wartości ocen cząstkowych można przetransformować według odpowiedniej funkcji do przedziału charakterystycznego dla zbioru rozmytego (rys. 8). Literatura nie podaje ogólnie obowiązujących reguł określania funkcji transformujących, ponieważ zależą one mocno od rozważanego problemu. Funkcje te są ustalane na bazie doświadczenia ekspertów oraz dostępnej wiedzy literaturowej. Oceny wszystkich wariantów dokonuje się oddzielnie względem poszczególnych kryteriów metodą Saaty'ego. Możliwe jest określenie przez każdego z ekspertów dla każdego kryterium dwóch granicznych funkcji transformujących dających w wyniku dwie różne wielkości z przedziału. Istnieje również możliwość przejścia z oceny o charakterze probabilistycznym w przestrzeń zbiorów rozmytych.



Rys. 7:. Zastosowanie symulacji komputerowej oraz wielokryterialnej oceny rozwiązań według metody Yagera w zarządzaniu zadaniami produkcyjnymi



Rys. 8. Transformacja ocen do zbioru rozmytego za pomocą funkcji transformujących sporządzonych przez poszczególnych decydentów

Biorąc pod uwagę p ekspertów, n wariantów oraz m kryteriów otrzymuje się $m \times p$ macierzy o wymiarach $n \times n$, na podstawie których tworzy się łączne (dla wszystkich decydentów) oceny rozmyte wariantów względem poszczególnych kryteriów o trójkątnych funkcjach przynależności (rys. 9).

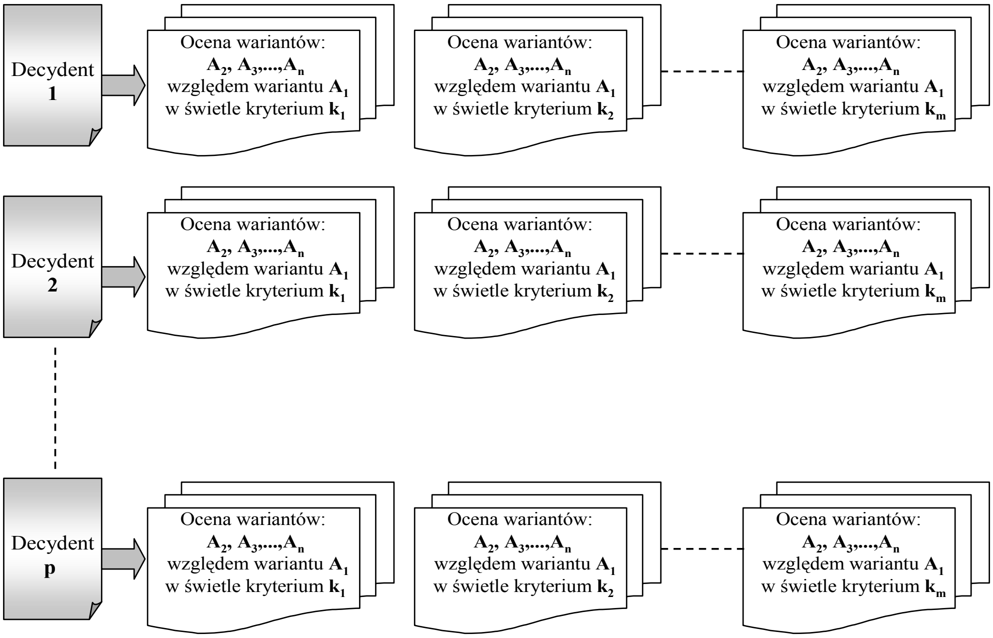
Kolejnym etapem oceny wielokryterialnej jest agregacja ocen cząstkowych przez tworzenie funkcji przynależności, określających całkowitą ocenę rozmytą poszczególnych wariantów. Agregacja ocen cząstkowych uzyskanych względem poszczególnych kryteriów wraz z uwzględnieniem ważności tych kryteriów może być wyrażona dla *i-tego* wariantu na podstawie wzoru 2.

$$Z_i = F(B_{i1}, B_{i2}, ..., B_{im}\ , w_1, w_2, ..., w_m) \qquad (2)$$

gdzie:

Z_i – zbiór rozmyty określony na przedziale <0,1>

F – funkcja agregująca



Rys. 9.: Wielokryterialna ocena wariantów względem wariantu bazowego dokonywana przez p decydentów według m kryteriów

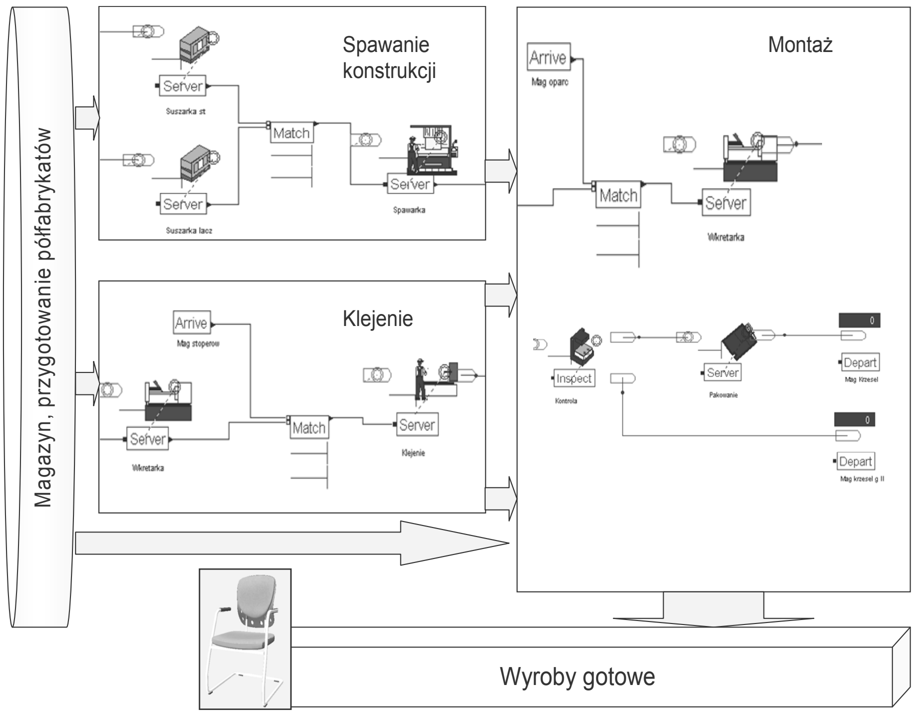
W dalszej kolejności należy uporządkować zbiory rozmyte zgodnie z przyjętą relacją porządkującą. Przykładową metodą porządkowania jest metoda przyporządkowująca każdej z funkcji przynależności jej średnią ważoną (wzór 3).

$$sw_i = \frac{\int_0^1 (z\ \mu_{z_i}(z))dz}{\int_0^1 \mu_{z_i}(z)dz} \tag{3}$$

Wariant *aj* jest bardziej preferowany niż wariant a_i, w przypadku gdy $sw_i < sw_j$. Najlepszym wariantem, spośród ocenianych, jest wariant najbardziej preferowany zgodnie z przyjętą relacją porządkującą. Opisane powyżej działania będą pomocne przy planowaniu eksperymentów symulacyjnych i doskonaleniu systemów produkcyjnych zmierzającym w kierunku obniżania kosztów produkcji oraz zwiększania wydajności.

4. Pryzkad wykorzystania symulacji oraz logiki rozmytej w doskonaleniu procesów produkcyjnych

Poniżej przedstawiono projekt analizy systemu wytwarzania mebli biurowych w oparciu o eksperyment symulacyjny na modelu komputerowym oraz wielokryterialną ocenę wariantów rozwiązań (rys. 10, 11, 12).



Rys. 10.: Model symulacyjny systemu produkcyjnego w pakiecie Arena

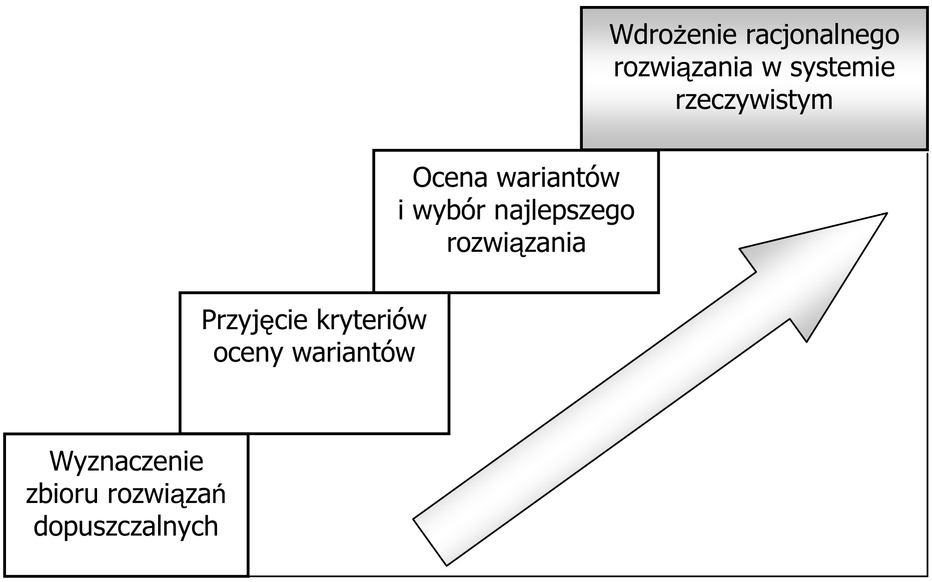
W wyniku przeprowadzenia projektu symulacyjnego procesów produkcji krzesła otrzymano raporty w postaci odpowiednich zestawień dotyczących (5):

- obciążenia poszczególnych stanowisk roboczych,
- wielkości kolejek,
- średniego okresu oczekiwania przed wybranymi stanowiskami,
- charakterystyki wąskich gardeł,
- wydajności systemu produkcyjnego.

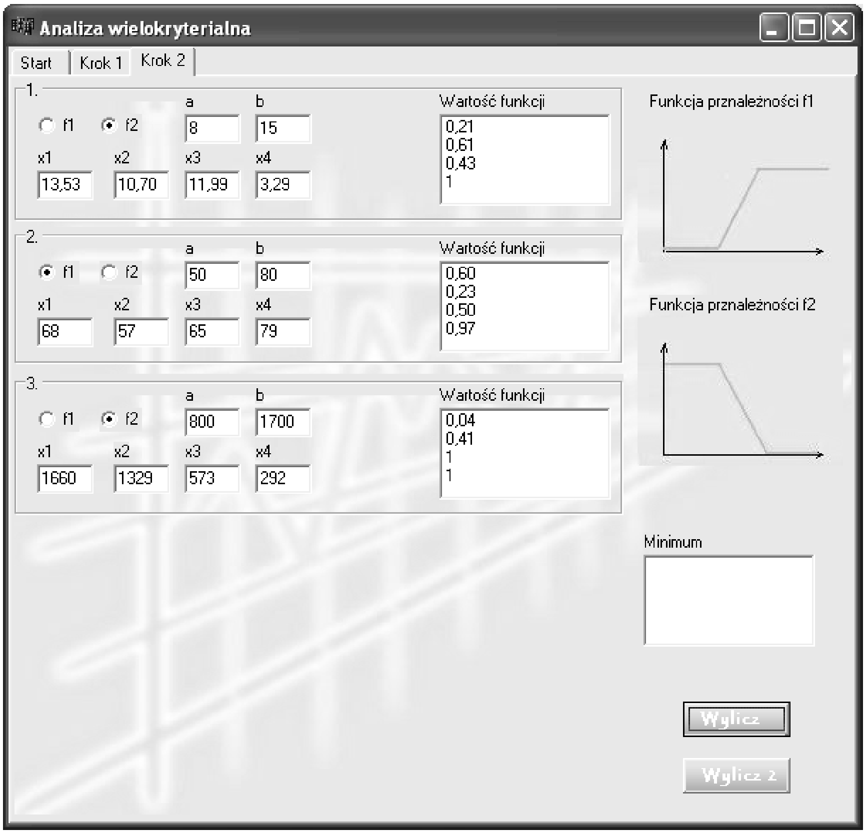
W ramach projektu analizie poddano 4 warianty przebiegu procesu produkcji mieszczące się w zbiorze wariantów dopuszczalnych ze względu na koszty oraz czas realizacji zleceń. Dobierano wymaganą ilość stanowisk produkcyjnych, ich rozmieszczenie oraz stopień automatyzacji. Analizowano również możliwość podjęcia kooperacji w ramach niektórych czynności. W dalszej kolejności wyznaczano koszty stanowiskowe dla poszczególnych rozwiązań.

Na etapie analizy opracowanych wariantów procesu produkcji krzeseł ustalono następujące kryteria oceny stanowiących wejścia do systemu:

- koszty stanowiskowe (k1),
- obciążenie stanowisk produkcyjnych (k2),
- wartość inwestycji w maszyny i urządzenia (k3).



Rys. 11.: Racjonalizacja systemu – etapy projektu



Rys. 12.: Ocena wariantów – określenie funkcji przynależności

Na podstawie opisanej wcześniej procedury oceny wariantów w oparciu o logikę rozmytą wyznaczono wynikowe funkcje przynależności dla poszczególnych kryteriów:

$$k_1 = \frac{0,2}{w_1} + \frac{0,6}{w_2} + \frac{0,4}{w_3} + \frac{1}{w_4} \tag{4}$$

$$k_2 = \frac{0,6}{w_1} + \frac{0,2}{w_2} + \frac{0,5}{w_3} + \frac{0,9}{w_4} \tag{5}$$

$$k_3 = \frac{0{,}04}{w_1} + \frac{0{,}4}{w_2} + \frac{1}{w_3} + \frac{1}{w_4} \tag{6}$$

W dalszej kolejności określono funkcję decyzyjną w następującej postaci:

$$p = \frac{0{,}04}{w_1} + \frac{0{,}2}{w_2} + \frac{0{,}4}{w_3} + \frac{0{,}6}{w_4} \tag{7}$$

Z przeprowadzonej analizy wynika, że najlepszym wariantem według przyjętych trzech kryteriów oceny jest rozwiązanie W4.

5. Podsumowanie

Symulacja jest złożonym procesem wykorzystywanym przy projektowaniu, planowaniu i sterowaniu przedsięwzięciami w różnorodnych dziedzinach gospodarki. Stała się jedną z ważniejszych technik wspomagających zarządzanie produkcją. Wiąże się to z tym, że w warunkach gospodarki rynkowej przedsiębiorstwa zmuszone są do rozwiązywania coraz bardziej złożonych problemów w coraz krótszym czasie.

Zastosowanie technik symulacyjnych w inżynierii produkcji pozwala na racjonalizację przepływów materiałowych oraz zmniejszenie zapasów produkcyjnych. Narzędzia symulacyjne dają możliwość poznania struktury i działania konstruowanych obiektów, opracowania algorytmów umożliwiających poprawę wskaźników jakości procesów wytwarzania oraz przewidywania wpływu zakłóceń na proces produkcji.

Zastosowanie narzędzi oceny wielokryterialnej wariantów usprawnień w systemach produkcyjnych pozwoli w prosty i skuteczny sposób wybrać racjonalny przebieg procesu produkcyjnego. Wprowadzając zmiany w funkcjonowaniu stanowisk roboczych należy brak pod uwagę wiele czynników, a efekty zmian analizować pod względem wielu kryteriów. Dzięki ocenie znaczenia poszczególnych kryteriów oraz uwzględnieniu ich wag w dalszym postępowaniu, będzie można ocenić poszczególne warianty przebiegu procesu, co ułatwi proces decyzyjny.

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PRODUCTION DECISION MAKING AIDED BY SIMULATION TECHNIQUES AND FUZZY SET LOGIC

Abstract

This work presents the possibility of using technology of modelling and simulation of productive systems in the management of manufacturing processes. Within framework of the presented study one has performed analysis of rationalizations in production system on the basis of enterprise in furniture industry. The tools of multi-criterion evaluation were used where criteria and variants were assessed by means of subjective point evaluation and fuzzy character evaluation.

Chapter 1.5.

PROCESY RIADENIA VZNIKU A IMPLEMENTÁCIE INOVÁCIÍ

MANAGEMENT PROCESSES OF INNOVATION INCEPTION AND IMPLEMENTATION

Branislav MIČIETA[1], Helena TUREKOVÁ[2]

Kľúčové slová: inovačný manažment, riadenie inovácií, komercializácia

Abstrakt
Organizácia, ktorá chce existovať v konkurenčnom prostredí globálnych trhov, nemôže ignorovať potrebu riadenia procesu vzniku a komercionalizácie inovácií. Riadenie inovácií (managing innovation) je stručným pomenovaním procesov, ktoré umožňujú vznik a realizáciu inovácií. Takéto chápanie je dôležitým preto, že v skutočnosti neriadime inovácie (keďže inováciou rozumieme výsledok úsilia vytvárania nových vecí), ale v organizácii riadime procesy umožňujúce vznik a realizáciu inovácií. Treba zdôrazniť, že vznik a realizácia inovácií v súčasnosti nepatrí k štandardizovaným podnikovým procesom. Inak povedané, v zmysle procesného riadenia organizácií, proces inovovania nie je zahrnutý do máp procesov organizácií. Uvedené poznatky vyvolávajú nasledovné otázky: Prečo tomu tak je? Je vôbec potrebné hovoriť o procese inovovania ako o podnikovom procese? Ak áno, tak prečo? Ak nie, tak ako zabezpečiť, aby vznik inovácií nebol len náhodným javom? Odpovede na tieto i ďalšie otázky s tým súvisiace sú rozdelené do troch častí. Prvá časť je venovaná pomenovaniu súvislostí medzi zabezpečovaním chodu podniku a rozvoja podniku prostredníctvom inovácií, pričom je uvedený jeden z možných pohľadov na teórie riadenia inovácií. Druhá časť je venovaná popisu jednotlivých fáz procesu inovovania z pohľadu riadenia vzniku inovácií ako súčasti interných procesov podniku a tretia je prepojením medzi touto kapitolou a metodickými postupmi riešenia inovačných projektov.

[1] **Prof. Ing. Branislav Mičieta**, **PhD.**, Industrial Engineering Department, Faculty of Mechanical Engineering, University of Žilina, Univerzitná 1, 010 26 Žilina, Slovak Republic, tel. 00421-0415132702, e-mail: branislav.micieta@fstroj.uniza.sk http://fstroj.utc.sk/web/kpi/

[2] **Doc. Ing. Helena Tureková, PhD.,** Industrial Engineering Department, Faculty of Mechanical Engineering, University of Žilina, Univerzitná 1, 010 26 Žilina, Slovak Republic, tel. 00421-0415132709, e-mail: helena.turekova@fstroj.uniza.sk

1. Riadenie inovácií a rozvoj podniku

Inovácie sú viditeľnými výsledkami navonok neviditeľných procesov, ktoré musia byť riadené. Prax potvrdzuje, že medzi rozvojom podniku a vznikom inovácií je úzka väzba. Inováciami možno podporiť rozvoj podniku a naopak, rozvoj podniku spravidla vytvára vhodné prostredie pre vznik inovácií. V nasledovnom bude bližšie objasnená daná väzba.

Úrovne rozvoja podniku

Pre získanie komplexného pohľadu na rozvoj podniku je vhodné využiť model šiestich úrovní rozvoja podniku, znázornený na obr.1. Podľa (4), tento model umožňuje dobre štruktúrovať všeobecné i špecifické podmienky rozvoja podniku.

Podniková kultúra, ktorá je prejavom myslenia a správania sa pracovníkov, odráža aj ich prístup k zmenám a schopnosť aktívneho zapojenia sa do procesov inovovania.

Obr..1: Šesť úrovní rozvoja podniku podľa (4)

Podniková kultúra je najvyššou úrovňou v modeli rozvoja podniku. Buduje sa dlhodobo na základe spolupráce a vzájomných vzťahov medzi pracovníkmi podniku navzájom i medzi podnikom a jeho partnermi. Je odrazom predstáv, hodnôt a prístupov všeobecne zdieľaných, v podniku dlhodobo udržiavaných. Konkretizovať predstavu podnikovej kultúry je možné pomocou popisu jednotlivých prvkov nasledovne:

- predstavy o vlastnej práci, o jej zmysle, o úspechu firmy, o odmeňovaní, atď.
- prístupy k práci, ku spolupracovníkom, k cieľom firmy, k inováciám, ku konfliktom, atď.
- hodnoty uznávané, rešpektované a rozvíjané.

Prístup ľudí k cieľom (podniku, pracovnej skupiny,... vlastným), k zmenám (k ich prijímaniu a aktívnej účasti), inováciám a ku spolupracovníkom, má značný vplyv na dosahovanie úspechu v podobe zmysluplných výsledkov práce. Otázka prístupu k niekomu či niečomu je otázkou bytostne ľudskou, je to i vec zaužívaného správania sa. Zaužívané správanie sa pracovníkov podniku je buď v súlade s kultúrou inovatívnej firmy, alebo je pre vytvorenie požadovanej kultúry firmy potrebné vyvolať zmenu správania sa ľudí.

Zmeniť prístupy, zmeniť zaužívané správanie sa ľudí je nie jednoduché, ale možné. Okrem zmeny vlastného správania, manažéri môžu v priebehu času dosiahnuť cielenú zmenu vytváraním prostredia, v ktorom budú dodržiavané pravidlá podporujúce požadovanú kultúru. Súbor pravidiel bude vždy závisieť od konkrétnej spoločnosti, avšak je možné určiť rámec takýchto odporúčaní. Hierarchia úrovní (obr.1) naznačuje úzku väzbu medzi podnikovou kultúrou a konaním vrcholových manažérov podniku, ktorí určujú stratégie pre dosiahnutie dlhodobej prosperity, a teda významne ovplyvňujú i postoj k otázke inovácií.

Sociálno-psychologická úroveň sa týka rozvoja pracovníkov a budovania medziľudských vzťahov. Rozvoj tejto úrovne je pre riadenie inovácií kľúčový, keďže tvoriví jednotlivci sú žriedlom nových nápadov a prostredníctvom spolupráce ľudí je možné nové nápady aj zrealizovať. Spoločnosť a jednotlivci (ľudský činiteľ) ako nositelia vedomostí, zručností a schopnosti uplatniť ich pri experimentovaní sú tým, čo umožňuje posúvať hranice možného. Avšak je nesporné, že pre získanie, udržanie a využívanie potrebného intelektuálneho kapitálu je potrebné mať vhodný systém motivácie a dostatočné zdroje.

Hospodársko - finančnej úrovni prináleží získavanie a efektívne udržiavanie všetkých druhov zdrojov. Otázka nutnosti tejto úrovne nebýva spochybňovaná. Skôr sa stretneme so situáciou, keď je pohľad enormne upriamený na získavanie čo najväčšieho množstva financií. Obstaranie kvalifikovaných pracovníkov, technológií a materiálneho vybavenia produkčných systémov je vždy spojené s nutnosťou zabezpečenia finančných zdrojov.

Informačné a hmotné toky v podniku tvoria základ pyramídy. S ich podporou sú realizované nutné výrobné procesy. Prax inovatívnych podnikov potvrdzuje, že čím viac sa darí zabezpečovať rozvoj na všetkých úrovniach podniku, tým sú vytvorené lepšie predpoklady pre vznik inovácií.

Pre každodennú prevádzku organizácií existujú štandardné postupy, ktoré ale v požadovanom rozsahu nezabezpečujú proces inovovania. Problém je v tom, že postupy, ktorými je zabezpečovaný chod organizácie, nie sú zamerané na realizáciu zmien, ktorých výsledkom sú inovácie. Vzniká otázka: Čo viac alebo čo iné je potrebné vykonať pre zvýšenie pravdepodobnosti vzniku inovačných nápadov a ich realizáciu v komerčnej sfére?

Skúsenosti ukazujú, že inovácie vyžadujú rozšíriť existujúce štandardné postupy o proces inovovania, ktorý vyžaduje zvláštnu sadu riadiacich znalostí a zručností.

Teórie riadenia inovácií

Názory na to, čo považovať za teóriu riadenia inovácií sa líšia práve tak, ako sa líšia názory na obsah samotného pojmu inovácia. V súvislosti s teóriou riadenia inovácie je možné uviesť niekoľko pozoruhodných konceptov inovatívneho myslenia a správania, ktoré majú svoje špecifické zameranie. Jednotlivé teórie sa odlišujú najmä tým, čo ich autori považujú za ústredný problém vytvárania nových vecí. Tak vznikli teórie, ktoré prioritne riešia riadenie vzniku a realizácie inovácií z pohľadu:

a) zavádzania technologických, tržných a organizačných zmien,
b) vytvárania hodnoty pre zákazníka,
c) marketingu,
d) strategického manažmentu.

Ad a)

Pohľad na riadenie inovácií, ako na zavádzanie technologických, tržných a organizačných zmien ponúkajú Joe Tidd, John Bessant a Keith Pavitt. Sú autormi knihy „Managing innovation“ (8), ktorá bola napísaná pre potreby postgraduálnych študentov manažmentu, najmä účastníkov programov MBA. Tento koncept poskytuje jeden z najkomplexnejších výkladov problematiky riadenia inovácií publikovaných v poslednom období. Vzhľadom k tomu, že umožňuje organické začlenenie inovačných projektov do procesu inovovania, je vhodný pre vytvorenie predstavy o praktických aplikáciách.

Ad b)

Uceleným konceptom, ktorý je možné považovať za teóriu riadenia inovácií je hodnotový manažment. Hodnotový manažment je štýlom manažmentu zameraným najmä na riadenie inovácií prostredníctvom motivácie, rozvíjania zručností a podporovania súčinnosti ľudí, s cieľom maximalizovať celkovú výkonnosť organizácie. Je to koncept riadenia inovácií overený početnými aplikáciami najmä v priemyselne vyspelých krajinách. Pre hodnotový manažment je vytvorený spoločný rámec a pravidlá uplatňovania prostredníctvom európskych noriem (14,15) a je pomerne precízne popísaný v dostupnej literatúre (10, 11). Uvedené fakty sú dôvodom pre využívanie hodnotového manažmentu ako metodickej podpory inovačných projektov. Ak porovnáme tento koncept s predchádzajúcim môžeme vidieť, že oba vyžadujú systémové myslenie. Vzájomne sa dopĺňajú tým, že koncept zavádzania technologických, tržných a organizačných zmien vytvára priestor pre riadenie inovačných projektov prostredníctvom aplikačných disciplín hodnotového manažmentu.

Ad c)

Vzhľadom na prepracovanosť obsahu a štruktúry inovatívneho marketingu môžeme tento ucelený pohľad na inovácie vznikajúce na existujúcich trhoch a inovácie vytvárajúce nové trhy považovať za špecifickú teóriu riadenia inovácií.

Ad d)

Špecificky zameraným je koncept riadenia inovácií, ktorý jeho autori predstavili pod názvom „Stratégia modrého oceánu“ . Prioritne sa zameriavajú na tvorbu stratégií inovovania, pričom hovoria o umení vytvoriť si zvrchovaný tržný priestor a vyradiť tak konkurentov z hry (3). Používajú predstavu tržného priestoru, ktorý tvoria dva druhy oceánov, červený a modrý. Červené oceány predstavujú všetky dnes existujúce odvetvia, ide o známy tržný priestor. Modré oceány sú označením pre všetky dnes neexistujúce odvetvia a pre tržný priestor, ktorý nie je dosiaľ známy. Myšlienky, nástroje a systémové rámce ktoré predstavujú sú popisované pomocou terminológie, ktorá síce zvyšuje lahodnosť čitateľského zážitku, sťažuje však zosúladenie tohto konceptu s praktickými postupmi inovovania.

Vyššie uvedené poznatky slúžia k získaniu objektívneho pohľadu na existujúce prístupy k vytváraniu teórií inovovania. Takýto pohľad môže pomôcť pri rozhodovaní o inováciách. Rozhodovanie o inováciách je možné za predpokladu základných znalostí o teórii a praxi riadenia inovácií, ako aj o spôsobe ich používania vo vlastnej organizácii. Dôvodom pre uvedené tvrdenie je nasledovná skúsenosť: pokiaľ sa nebudeme snažiť vedome prepájať teoretické poznanie s reálnymi životnými skúsenosťami, tak v inováciách pokročíme veľmi málo alebo vôbec.

Pre zabezpečenie realizácie procesu inovovania odporúčame v organizácii, na základe doterajších skúseností, realizovať aktivity ktoré možno rozdeliť do troch skupín:

Prvá skupina aktivít je zameraná na stanovenie pravidiel pre riadenie inovácií. Je potrebné pomenovať zásady a pravidlá pre dosiahnutie toho, aby každý v organizácii mohol nájsť odpoveď na otázky týkajúce sa:

- samotnej inovačnej stratégie spojenej s preferovaným spôsobom myslenia vedenia organizácie,
- organizačných podmienok zapojenia sa do inovačných procesov,
- zrozumiteľnosti väzieb vo vnútri i mimo organizácie,
- možností vlastného rozvoja a zapojenia sa do práce inovačných tímov,
- mechanizmu učenia sa prostredníctvom zdieľania znalostí.

Druhá skupina aktivít je zameraná na starostlivosť o tvorivý ľudský potenciál, čo znamená sústrediť sa na:

- osvojovanie si návykov podporujúcich rozvoj tvorivosti,
- získavanie ľudí pre zmeny,
- prekonávanie bariér,

- komunikáciu o inováciách,
- rozvoj schopností využívať metódy a techniky podpory inovatívnych riešení,
- zapojenie pracovníkov do riešenia inovačných projektov.

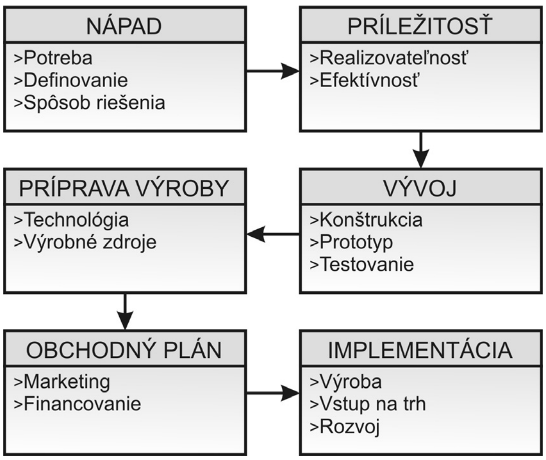
Treťou skupinou aktivít je zabezpečenie aktuálnych informačných tokov, ktorých výsledkom je získanie relevantných informácií a vedomostí, ku ktorým patrí:

- prieskum a zachytávanie signálov vonkajších zmien (trh, veda a technika),
- zdieľanie znalostí v sieťach,
- riadenie inovácií, resp. riadenie inovačných projektov.

Existuje viacero spôsobov, ako konkretizovať a realizovať v podnikovej praxi vyššie uvedené aktivity.

Klasický prístup k procesu inovovania

V minulom storočí bol u nás pomerne rozšírený výklad procesu inovovania, ktorý bol popisovaný ako proces vzniku výrobkovej inovácie. Vychádzal z poznania, že nápady iniciujú proces inovovania a podľa (26) je možné nápad považovať za súčasť inovačného procesu tak, ako to ilustruje obr.6.



Obr. 6.: ***Schéma inovačného procesu (26)***

V zmysle uvedenej schémy, je to logicky jasný proces, ktorý možno opísať nasledovne:

1. Inovácia štartuje z inovačného nápadu, ktorý identifikuje novú potrebu budúcich užívateľov, ale aj spôsobu ako túto potrebu zabezpečiť. Predpokladom je poznanie situácie, analýzy podmienok, vývojových trendov a iných dôležitých faktorov a návrh nového riešenia. Inovačný nápad je v ďalšom kroku podrobený analýze z hľadiska realizovateľnosti, osobitne s dôrazom pre zabezpečenosť zdrojov, know – how, technického vybavenia, financií, ľudských zdrojov, priestoru, partnerov a pod. Je treba hodnotiť trhový potenciál, predpoklady dosiahnutia ekonomických prínosov a návratnosti investícií. **V terminológii strategického manažmentu by sme mohli hovoriť o štúdii realizovateľnosti.**

2. Otestovaný inovačný nápad sa transformuje na inovačnú príležitosť.

3. V prípade priaznivých podmienok nastupuje fáza vývoja nového výrobku, služby, alebo organizácie. Praktické postupy sú závislé od inovačnej oblasti. Napr. pri strojárskych výrobkoch je to návrh výrobku, rozmerové a pevnostné výpočty, konštrukčné výkresy, realizácia prototypov a ich skúšky.

4. Ďalšie kroky inovačného procesu reprezentujú fázu materializácie inovácie t.j. prípravu výrobnej základne pre opakovanú výrobu. Záverečné fázy súvisia s trhovou aplikáciou inovácie.

Jednotlivé prvky takto popísaného procesu inovovania naznačujú, že predpokladaným výstupom je nový výrobok. Naše skúsenosti potvrdzujú, že nové výrobky ako hmatateľné výstupy ľudskej práce sú najlepšie viditeľnými inováciami a preto i proces „od nápadu k realizácii“ je najľahšie opísateľný v prípade vytvárania nového výrobku. Uvedenú schému je možné považovať za objasnenie procesu inovovania výrobku, so zameraním na špecifikáciu odborných činností, ktoré sa na tomto procese podieľajú. Z pohľadu možností uplatnenia simultánneho inžinierstva i aplikácie nových informačných technológií viazaných na vytvorenie konštrukčného návrhu, prototypu a návrhu výrobných systémov sa uvedená schéma na obr.6 javí ako prekonaná.

Za výklad problematiky riadenia procesu inovovania, ktorý spĺňa požiadavku využitia aktuálnych poznatkov je možné považovať koncept zavádzania tržných, technologických a organizačných zmien (ad a). Tento koncept dôsledne uplatňuje procesný prístup pri koncipovaní uceleného systému pre integráciu riadenia inovácií, preto pri konkretizácii procesu inovovania v priemyselnom podniku budú použité odporúčania jeho autorov (49).

Nasledujúca časť je venovaná riadeniu vzniku inovácií, pričom vychádzame z predpokladu, že proces inovovania je jedným z kľúčových procesov inovatívneho podniku.

2. Riadenie vzniku inovácií ako súčasť interných procesov

Každého inovátora zaujíma ako dosiahnuť, aby pracovníci prichádzali so skvelými nápadmi, ktoré prinesú zmysluplné inovácie a do ktorých sa oplatí investovať.

Mam nápad – často je výkrikom jedinca bez odozvy. Ak výkrik ide do zabudnutia, na jedinca to môže pôsobiť domotivujúco a organizácia môže prísť o príležitosť využiť nový nápad. Nebolo by tomu tak, keby v organizácii bol zavedený jasný mechanizmus na ošetrenie vzniknutého nápadu. Pre modernú organizáciu i to je málo, pretože je žiaduce vytvoriť mechanizmus i na to, ako podporovať vznik nápadov. Každá organizácia by si mala vytvoriť vlastný model pre realizáciu inovačných aktivít, pričom musí využívať svoje silné stránky v tejto oblasti.

Vznik inovácií ako proces

Inovácie z hľadiska veľkosti zmeny sa delia na inkrementálne a diskontinuálne. Pre riadenie procesu vzniku inovácií je toto členenie dôležité, nakoľko majú rozdielne podmienky informačných vstupov a preto vyžadujú rozdielny prístup k ich riadeniu.

Inkrementálna inovácia je potenciálne riaditeľná, pretože začíname s niečím, čo poznáme a od toho odvíjame zlepšenia. Ako sa presúvame k možnostiam radikálnejších zmien, miera neistoty sa zvyšuje. Od istého bodu vstupujeme do neznáma, kedy je potrebné vymyslieť niečo, čo dosiaľ neexistovalo.

Existujú metodické postupy, ktorými sa môžeme dopracovať k vytvoreniu nového technického systému, k navrhnutiu novej technológie, k navrhnutiu riešenia problému, pričom toto nové riešenie bude jedinečné, správne a dosiaľ neuskutočnené. V prípade diskontinuálnej inovácie sú vysoké nároky na predstavivosť. Tento uhol pohľadu pomáha pochopiť, prečo vytvorenie napríklad technického objektu vyššieho inovačného rádu vyžaduje špeciálne podporné metodické nástroje a nestačí uplatnenie jednoduchých metód tvorivosti typu brainstorming. Viď popis metodík (1,9,11).

Uvedomenie si, že záleží na spôsobe ako je proces vzniku inovácií riadený, vedie k snahám tento proces spoznať, porozumieť tomuto procesu, popísať ho a riadiť tak, aby náhode bol ponechaný minimálny priestor.

Vo všeobecnosti musí organizácia pri realizácii inovačného procesu riadiť aktivity vo všetkých jeho špecifických fázach tak, ako sú popísané v tab.1.

Tento proces má zabezpečiť obnovu (renováciu) toho, čo organizácia ponúka, akým spôsobom to vytvára a dodáva. Odlišné situácie v konkrétnych organizáciách vedú k odlišným riešeniam. Samotné inovácie sa navzájom líšia v rozsahu, povahe, miere novosti – rovnako tak sa líšia i inovujúce organizácie a spôsoby procesov inovovania. Čo je spoločné, to je cesta ktorú všetci musia prejsť. Možno ju naznačiť nasledovne:

spracovanie signálov → strategický koncept → vývoj produktu a príprava trhu → *uvedenie na trh*.

Tab.1.

Popis fáz procesu inovovania

Fázy	Aktivity organizácie
Fáza 1	Generovať nápady - sledovať a skúmať svoje prostredie (interné i externé), aby bola schopná rozpoznať a spracovať signály potenciálnych inovácií (spúšťače inovácií).
Fáza 2	Cielene vybrať nápady (podnety), investovať do vybranej voľby (výberu) a získať znalostné zdroje (výskum, licencie a pod.).
Fáza 3	Implementovať inováciu, t.j. previesť ju z podoby nápadu (prvotnej myšlienky) cez potrebné štádiá vývoja až po finálnu realizáciu.
Fáza 4 (voliteľná)	Učiť sa zo skúsenosti, čo je možné reflexiou predchádzajúcich fáz a analýzou dosiahnutých výsledkov (úspechov a neúspechov).

Ako dosiahnuť to, aby sa proces inovovania stal súčasťou prirodzených a pracovníkmi osvojených spôsobov myslenia a správania sa, bude predmetom nasledovného popisu fáz procesu inovovania - ako interného procesu.

Fáza 1: Generovanie nápadov realizáciou efektívneho prieskumu

Podobne ako antény zachytávajú signály z okolia, tak ľudia sledovaním prostredia ktorého sú súčasťou, môžu získať signály pre potenciálne inovácií. Tieto signály sa môžu týkať technológie, trhu, správania sa konkurencie, zmien v politickom alebo legislatívnom prostredí či nových sociálnych trendov, pričom môžu pochádzať zvnútra i zvonku organizácie. Skúmanie zmien v uvedených oblastiach sa bežne realizuje v rámci zaužívaných odborných činností v organizácii (marketing, kvalita, ...). Z hľadiska procesu inovovania je však potrebné zabezpečiť, aby sa:

- hranice skúmaného priestoru rozšírili a vytvorili nový priestor (pre pôsobenie),
- získané informácie pružne šírili a boli zdieľané vo vnútri organizácie.

Zo strany manažérov je žiaduce podporovať zvedavosť pracovníkov o novinky v oblasti ich odbornej práce a odmeňovať záujem o nové veci.

Vzhľadom na to, že ide o získanie a šírenie podnetných informácií, je to predovšetkým problém komunikácie, motivácie, organizačného a technického zabezpečenia získavania, uchovávania, triedenia a distribúcie informácií.

Netreba zabúdať že v jednotlivých odborných útvaroch organizácie sa získavajú a existujú informácie, ktoré môžu byť spúšťačmi mechanizmu inovácie. Napríklad informácie o nových konkurenčných produktoch, nových požiadavkách zákazníkov, o chybách vyžadujúcich zmenu pracovných postupov a podobne.

V tejto fáze procesu inovovania je dôležité monitorovať nasledovné oblasti:

1. Trh - ako množina solventných zákazníkov ochotných kúpiť.
2. Zákazníci - ako konkrétni partneri v procese obchodovania.
3. Technológie - ako špecifické a opakovateľné spôsoby dosiahnutia zmien.

4. Ekonomika a spoločnosť - ako svet v ktorom žijeme a ktorý sa vyvíja.
5. Interní pracovníci - ako žriedlo nápadov a riešení.

Každá fáza procesu inovovania je spojená s učením sa skúsenosťou. Prvá fáza je špecifická v tom, že dominuje učenie sa zo skúseností iných. K tomu patrí porovnávanie sa s konkurenciou a inými organizáciami, získavanie poznatkov z úspešných projektov riešených inými organizácií, alebo metódy reverzného inžinierstva. Rad priemyselných podnikov vďačí za svoj úspech stratégii kopírovania a následného vývoja, čo je v zásade učenie sa od iných. Ďalším súvisiacim zdrojom inovačných signálov môžu byť aj omyly a neúspechy, ktoré niekedy otvárajú celkom nové smery úvah, a tým aj podnety pre inovácie.

Príprava ľudí pre zapojenie do procesov vzniku inovácií bude hrať stále väčšiu rolu. Nezahŕňa len vybavenie pracovníkov potrebnými vedomosťami, ale väčšiu váhu má ich získanie pre aktivity budovania siete znalostí. Nestačí len získať či zachytiť signály pre inovácie – treba ich spracovať a odovzdať ďalším ľuďom v organizácii.

Fáza 2: Cielený výber nápadov a voľba v súlade s rozvojovými smermi

Výsledkom prieskumu a sledovania prostredia (fáza 1) je získanie súboru nápadov, použiteľných pre formuláciu inovačných cieľov. V druhej fáze je potrebné rozhodnúť, ktorý nápad vybrať a ktorý nie. Pre to nestačia iba informácie o tom, čo teraz chcú zákazníci a čo teraz robí konkurencia. Je žiaduce chápať aj kľúčové parametre podnikateľského prostredia a poznať vplyv miery osvojenia technológií na možnosti ich plného využívania. Treba sústrediť pozornosť na poznanie toho, aké výhody prinášajú existujúce technologické znalosti, ako ich kumulovať, zdieľať a implementovať do nových produktov alebo procesov. A zaiste i to, ako k ním možno získavať potrebné doplnkové znalosti. Tieto požiadavky súvisia nielen s riadením procesov učenia sa v rámci firmy, ale aj so stratégiou investícií a akvizícií.

Na podporu procesu rozhodovania a pre úspech inovovania je kritické vytvorenie efektívnych postupov, keďže je potrebné zabezpečiť, aby vygenerovanie dobrých nápadov nebolo zbytočnou aktivitou snaživých jednotlivcov.

Strategické rozhodovanie patrí jednoznačne do kompetencií členov vrcholového manažmentu. Ich úlohou je teda i cielený výber a voľba signálov potenciálnych inovácií, ktoré sú v súlade so strategickými cieľmi organizácie. Zjednodušene povedané, je potrebné nájsť odpoveď na to, čo je potrebné urobiť pre uskutočnenie správnej voľby. Jednoduchá otázka, ale pre získanie odpovede je potrebné vykonať analýzy a na ich základe rozhodnúť, ktoré nápady budú ďalej rozvíjané prostredníctvom projektov, v akej výške im budú pridelené zdroje a určiť spôsob zabezpečenia monitoringu ich riešenia.

Pre úspešné zvládnutie tejto fázy poskytujeme čitateľovi výber poznatkov a overených odporúčaní, ktoré sú rozdelené do nasledovných častí:

1. Analýza a činnosti s ňou spojené
2. Voľba a rozhodnutie
3. Monitorovanie

Fáza 3: Implementácia inovácie

V rámci implementácie inovácie ide o transformáciu vybraného nápadu do reálnej podoby. Tento proces vyžaduje realizáciu nasledovných krokov:

- získanie potrebných znalostí pre otvorenie konkrétneho inovačného projektu,
- riešenie inovačného projektu a
- zavedenie výsledku inovačného projektu (inovácie) na trh a jeho udržanie na trhu.

Pokiaľ si podnik nemôže dovoliť investovať do vlastného výskumu a vývoja, je potrebné nájsť spôsob využitia technológie, ktorú vytvorili iní, alebo vhodne doplniť kľúčovú technológiu podniku. Ďalšou možnosťou ako nahradiť vlastný výskum je koncepcia tzv. otvorených inovácií, ktorá je dnes uplatňovaná viacerými veľkými organizáciami. Napríklad firma Henkel je známa svojou výzvou všetkým vynálezcom s prísľubom určitého podielu na budúcich ziskoch.

Vytváraniu nových technológií sa môžeme vyhnúť, ak sme súčasťou fungujúcej siete spolupracujúcich organizácií. Vyžaduje to však schopnosti vyhľadávať, vyberať a prenášať technológiu z vonkajšieho prostredia do vlastnej organizácie. Ku kľúčovým schopnostiam potrebným pre presun technológie patrí najmä vybudovanie resp. udržiavanie postavenia v sieti technologických lídrov, zabezpečenie súladu medzi internými potrebami a externou ponukou a efektívny transfer s následným učením sa a osvojením si transferovanej technológie.

Efektívne získavanie znalostí realizované v prvom kroku implementácie inovácie je dôležité najmä pre získanie faktov, na základe ktorých je možné cielene otvoriť riešenie konkrétnych inovačných projektov. Je samozrejmosťou, že o efektívne získavanie znalostí usiluje každý z riešiteľov projektu.

V prvých fázach riešenia inovačných projektov je možné zmeniť prakticky všetko, ale so zvyšujúcim sa objemom vložených zdrojov je stále ťažšie zásadne meniť smerovanie projektu. Značným nebezpečenstvom môže byť i predčasné ukončenie projektu. V tomto prípade sa vystavujeme riziku, že nedopracujeme inováciu, ktorá by mohla vzniknúť pokračovaním riešenia projektu, pričom by mohla dosahovať kvalitatívne nový rozmer. Rozhodovanie o pokračovaní resp. zastavení projektu je žiaduce vykonávať systematickým spôsobom, čo vyžaduje jasne stanoviť body, v ktorých sa bude rozhodovať (pokračovať/nepokračovať) a dohodnúť vopred jasné pravidlá rozhodovania.

Paralelne s riešením samotných technických problémov, týkajúcich sa vzniku inovácie, mali by prebiehať činnosti spojené s prípravou trhu, na ktorý má byť inovácia uvedená. Otázka prijatia niečoho nového je otázkou priebehu vnímania, záujmu, vyskúšania, ohodnotenia a prijatia. Aspekt zvažovania vnímania nového produktu spotrebiteľom môže byť zakomponovaný do metodického postupu samotného procesu vzniku inovácie.

V prípade implementácie procesnej inovácie vo vlastnej organizácii navyše vyžaduje zvláštne zručnosti v oblasti riadenia zmien. V tomto prípade sa kladie zvýšený dôraz na komunikáciu, zapojenie účastníkov a ich intervenciu (napríklad prostredníctvom školení , tréningu, ...), aby sa minimalizoval odpor ku zmene.

Proces inovovania je dynamickým procesom. Dynamika tohto procesu je zabezpečovaná kontinuálnymi inovačnými cyklami rôznej intenzity. Je to dôsledok skutočnosti, že uvedenie inovácie na trh je stimulom pre nový inovačný cyklus.

Fáza 4: Učenie sa zo skúseností

Získané riešenia možno vyhodnotiť nielen po ukončení celého projektu, ale aj v jeho míľnikoch. Zo spätného pohľadu na priebeh riešenia riešitelia môžu získať cenné informácie z dokončených projektov – môžu sa učiť vlastnou skúsenosťou. Otázka je, ako sa táto možnosť využíva v praxi. Prax ukazuje, že tu existujú veľké rezervy. Veď naformulovať všetky získané poznatky (úspech i neúspech) a premeniť tacitné znalosti na explicitné (premeniť skúsenosť na komunikovateľnú znalosť), to vyžaduje úsilie, ochotu a najmä vedomie, že pracujeme pre budúcnosť. Týmto spôsobom sa dá vytvoriť znalostná báza organizácie, ktorá môže výrazne prispieť k rozvoju učiacej sa organizácie. Učenie sa vlastnou skúsenosťou sa môže týkať nielen technických poznatkov, ale aj schopností a postupov potrebných pre efektívne riadenie inovácií.

Väčšina inovačných projektov je riešená v praxi interdisciplinárnymi tímami (konštruktérmi, technológmi, priemyselnými inžiniermi, výrobcami, predajcami a užívateľmi), kde dochádza ku zdieľaniu poznatkov, pohľadov a názorov riešiteľov rôznych profesií. Preto je tu žiaduca súhra a vzájomné učenie sa. Na viac tu dochádza k využívaniu prvkov simultánneho inžinierstva, čo vyžaduje vzájomný rešpekt a porozumenie. Ďalšou výhodou simultánneho inžinierstva je to, že nám umožňuje včas identifikovať potenciálne konflikty.

Ku všeobecným predpokladom realizácie inovačných projektov patrí vytvorenie vhodného organizačného prostredia, ktoré bude podporovať tímovú spoluprácu v rámci podniku i v rámci vybudovaných sietí spolupracujúcich organizácií.

Efektívne riadenie inovačných projektov vyžaduje zaistiť, aby všetci v tíme smerovali k rovnakému, jasne stanovenému cieľu. Aj keď to znie ako samozrejmosť, nie vždy sa to podarí zabezpečiť. Ľahko sa stratí orientácia a spoločné zameranie hlavne v prípade, ak nie je dostatočne zdieľaná a komunikovaná spoločná vízia. Treba si uvedomiť, že iba dobre komunikovaná spoločná vízia nám umožňuje správne sa zamerať i na väčšie množstvo paralelných inkrementálnych inovačných aktivít a zabezpečiť nevyhnutnú vzájomnú informovanosť.

3. Odporúčania pre riešenie inovačných projektov

S inováciami sa vždy spája hľadanie cesty od nápadu k úspešnej realizácii, od impulzu pre zmenu k jej prijatiu. Vzhľadom na to, že inovačné projekty vyžadujú maximálne využitie tvorivého potenciálu projektového tímu a jeho spolupracovníkov, vyžaduje sa pri nich okrem metodickej podpory a zodpovedajúceho technicko-technologického vybavenia silná podpora zo strany vrcholového manažmentu. Táto je zvyčajne zabezpečená niektorým z členov vedenia firmy. Od tohto člena sa očakáva silné zaujatie pre realizáciu nápadu.

Prevláda presvedčenie, že implementácia inovácie formou projektu je správnou odpoveďou na to, ako zvládnuť zmeny, pretože projekt v tomto prípade možno charakterizovať ako dočasné úsilie zamerané na vytvorenie jedinečného produktu.

Pre uľahčenie riadenia projektov sú v nasledovnej časti uvedené dôležité poznatky a odporúčania. Z dôvodu ich praktického zamerania sú rozdelené do nasledovných častí:

- riadenie inovačného projektu (otázka projektového manažmentu),
- metodická podpora samotného riešenia projektu (otázka vecného riešenia úlohy).

3.1. Riadenie inovačného projektu

Vo všeobecnosti projektom rozumieme sekvenciu činností, ktorá má formálny začiatok a koniec, pridelené zdroje a smeruje k vytvoreniu určitého produktu. Existujú štyri typické znaky projektov ktoré ich odlišujú od iných manažérskych činností (pokiaľ sa vyskytujú spoločne). Jedná sa o to, že projekty majú trojrozmerný cieľ, sú jedinečné, zahrňujú zdroje a realizujú sa v rámci organizácie. To, že majú trojrozmerný cieľ znamená, že musia byť súčasne splnené nasledovné požiadavky: vecné uskutočnenie, dodržanie časového plánu a rozpočtových nákladov. Každý projekt je jedinečný, pretože sa realizuje len raz, je dočasný a (temer v každom prípade) na ňom pracuje iná skupina ľudí. Vyššie uvedené charakteristiky vytvárajú predpoklady pre vytvorenie unikátneho nového výrobku alebo služby v definovanom čase a pri spotrebe obmedzených zdrojov.

Metodickú bázu pre riadenie inovačných projektov poskytuje teória projektového manažmentu. Projektový manažment s vlastnou teóriou a pragmatickými postupmi a aplikáciami ošetruje dve zložky:

- riadenie projektov - zabezpečuje výber, riešenie a realizáciu projektov,
- vytváranie projektového prostredia je zamerané - na dosiahnutie súladu podnikovej stratégie a inovačných projektov, koordináciu súboru projektov, technickú a manažérsku podporu projektov, ako aj na vytváranie projektovej organizačnej štruktúry.

Aplikácia projektového manažmentu v podniku, je pre riadenie inovácií jedným z organizačných predpokladov dosiahnutia úspechu. Teória riadenia projektov, tak ako je rozvinutá v projektovom manažmente pre riešenie projektu, ponúka metódy a odporúčania zamerané na plánovanie a kontrolu efektívnosti využívania času a pridelených zdrojov.

Podľa (6) projekty vývoja nových produktov tvoria najväčšiu časť všetkých projektov a majú viaceré výnimočné rysy. Čím sa líšia od iných projektov je možné stručne charakterizovať nasledovne:

1. Konkurenčný tlak, najvhodnejší okamžik pre využitie obchodnej príležitosti a výhody prvého na trhu vedú k tomu, že najkritickejšou časťou projektu je obvykle plnenie plánovaných termínov.
2. Dosiahnuté parametre produktu sú výsledkom marketingového kompromisu medzi odhadom času, ktorý je k dispozícii, a výhodami, ktoré má nový produkt priniesť budúcim užívateľom. Požiadavky na produkt musia tiež zahŕňať výrobné náklady a cieľovú predajnú cenu.
3. Kritickým bodom je rozdeľovanie obmedzených zdrojov (hlavne ľudských, ale tiež materiálnych) medzi vzájomne si konkurujúce investičné príležitosti pre projekty.
4. Projekty obvykle zadáva a financuje vlastná organizácia, zriedka sa realizujú formou kontraktu na dodanie určitého výsledku inou organizáciou.
5. Vývoj nových produktov zahŕňa mnoho rôznych druhov projektov. Môže ísť o veľmi malé projekty alebo rozsiahle projekty. Technologická náročnosť môže byť malá alebo môže vyžadovať zložitú integráciu niekoľkých technológií. **Napríklad vývoj nového lekárskeho diagnostického systému môže využívať technológie z oblasti**

medicíny, mechaniky, optiky, elektroniky, chémie i softvérového inžinierstva.

6. Je dôležité uspokojiť ako zákazníka (produkt kupuje), tak užívateľa (produkt skutočne používa). Vo väčšine prípadov vedie od výrobcu k miestu predaja distribučný kanál a jeho sprostredkovatelia (maloobchodné reťazce, veľkoobchodní distribútori, obchodní zástupcovia výrobcu,...) sa významnou mierou podieľajú na úspechu/neúspechu produktu.
7. V priebehu vývoja prebieha nepretržitý prieskum trhu.
8. Časovo náročný a nákladný vývoj nového produktu už sám o sebe vyžaduje multiprofesijný projektový tím a koordináciu všetkých činností.

Ak k uvedeným znakom projektov vývoja nových produktov pridáme zoznam problémov, ktoré môžu nový produkt postihnúť keď sa dostane na trh a problémy s prideľovaním zdrojov, možno si vytvoriť predstavu o nárokoch na riadenie inovačných projektov, ktorých výsledkom je nový produkt.

Pri riešení inovačných projektov môžeme postupovať rôzne. Avšak vždy je určený manažér projektu a v zmysle pravidiel projektového manažmentu je mu pridelená právomoc i zodpovednosť za spôsob zabezpečenia koordinácie práce členov projektového tímu. Ciele sú spravidla jasne a presne stanovené a dôraz na splnenie stanovených cieľov pri dodržaní časových a zdrojových limitov je považovaný za samozrejmosť. Najčastejšie nastáva prípad, že manažér projektu alebo vedúci projektu plnia i rolu metodika, teda rozhodujú o postupoch, ktorými sa projektový tím dopracuje v jednotlivých fázach riešenia k požadovaným výsledkom. V prípade inovačných projektov, ktoré sú realizované v spolupráci s poradenskou spoločnosťou, úlohu metodika preberá poradca. Takto je to i v prípade vývoja nových produktov, navrhovania nových produkčných systémov, či zavádzania nových rozvojových konceptov.

3.2. Metodická podpora riešenia inovačného projektu

Teória projektového manažmentu nerieši otázku metodickej podpory riešenia problémov, ktoré sú predmetom inovačného projektu. Pre cielené riešenie vytvárania inovácií sa v priebehu druhej polovice minulého storočia vyvíjali špecifické metodické nástroje a metódy pre uskutočnenie činností v jednotlivých fázach riešenia inovačného projektu. V tomto smere môžeme zaznamenať praktiky v širokej škále - od intuitívneho používania metód tvorivého myslenia, cez heuristické postupy až po ucelené metodiky. Orientovať sa v množstve metód a metodík a získať zručnosť voľby vhodného metodického nástroja pri riešení konkrétnych úloh je často náročné. Odlišovať metódy a metodiky je užitočné, najmä preto aby sme mohli posúdiť vhodnosť ponúkaných metodických nástrojov vzhľadom na náročnosť riešeného problému.

Pri riešení menej zložitých technických problémov, resp. inkrementálnych inovácií môžu ako podpora hľadania nových riešení postačovať jednoduché metódy, známe ako metódy tvorivej tímovej práce. V súčasnosti je vybudovaný i publikovaný pestrý súbor metód tvorivého myslenia, ktoré je možné použiť pre vymýšľanie nových riešení (9, 11, 12). Metódy tvorivého myslenia z hľadiska inovačnej praxe sú prínosom iba vtedy, ak ich dokážeme vhodne použiť. Dôležitejšie, ako poznať tieto metódy, je mať osvojený spôsob myslenia ktorý aktivuje tvorivosť a racionálne správanie ľudí.

Pokiaľ usilujeme o vytvorenie inovácie, ktorá bude vykazovať vyššiu mieru novosti, resp. usilujme o diskontinuálne inovácie, prípadne riešime zložitý technický problém, potrebujeme silný metodický nástroj - typu komplexná metodika.

I keď vlastné metodiky podnikov ako aj metodiky poradenských organizácií môžu byť mimoriadne zaujímavé a účinné, pre potreby všetkých sú k dispozícii iba tie, ktoré sú publikované, všeobecne prístupné a overené praxou. Z kategórie publikovaných metodík majú špecifické postavenie metodiky založené na funkčne - nákladovom princípe (9). Odporúčame sa zamerať na hodnotový manažment, metodiku TRIZ a metódu WOIS.

Skúsenosti s používaním hodnotového manažmentu pri riešení inovačných projektov v priemyselnej praxi sú publikované (s detailným výkladom celkovej filozofie i metodického komplexu v jednotlivých fázach inovačného procesu) v (10, 11, 12). Tieto publikácie môžu slúžiť ako študijný materiál pre metodikov a zároveň ako rámec pre vytváranie vlastných aplikácií.

Metodika TRIZ svojimi analytickými a syntetickými metódami predstavuje kombináciu dialektickej logiky, psychológie tvorivosti a vynálezcovskej skúsenosti. Spája v sebe vedeckú a technickú tvorivú prácu, pomáha premietnutiu ľudského poznania prírodných vied do zmodernizovanej alebo novej techniky. Obsahuje dve navzájom sa dopĺňajúce časti, ktorými sú funkčne–nákladová analýza zdokonaľovaného systému a metóda ARIZ (Algoritmus Riešenia Invenčných Zadaní). Záujemcom o uvedené metodické nástroje možno odporučiť publikácie, ktoré približujú filozofiu a postupy vedúce k tvorbe a riešeniu inovačných zadaní vhodných najmä pre navrhovanie technických systémov (1). Z tohto pohľadu metodiku TRIZ je možné považovať za špecifickú nadstavbou hodnotového manažmentu. Vďaka počítačovej podpore (v súčasnosti túto podporu zabezpečuje softvérový systém Invention Machine), vytvára možnosť efektívneho využívania celosvetovej databázy patentov, čo najmä v počiatočných etapách vývoja nových výrobkov silne podporuje tvorbu riešení vyšších inovačných radov.

TRIZ patrí k pokročilým nástrojom podpory vzniku inovácií. Potreba riešenia zložitých technických problémov však vyžaduje nájsť spôsob, ako prostredníctvom špecializovaných pracovísk uvedené nástroje využívať v priemyselnej praxi. Dôsledné uplatnenie aplikácií hodnotového manažmentu a metodiky TRIZ v priemyselnej praxi vyžaduje kvalifikovaných (vyškolených) metodikov. I napriek svojej náročnosti je metodika TRIZ používaná.

Signálom aktuálnosti hodnotového manažmentu je prijatie európskych noriem (14, 15), ktoré štandardizujú tento koncept pre európsky trhový priestor. Hodnotový manažment po silnom útlme v roku 1989 zatiaľ v našom podnikateľskom prostredí nie je dostatočne využívaný (podľa našich znalostí). Prináša však vzor pre uplatnenie systémového myslenia, ktoré je vhodné pre tvorbu vlastných metodických postupov s využitím funkčne-nákladového (hodnotového) princípu.

Spokojnosť zákazníka a ekonomickosť produkcie sú dôvodmi, pre ktoré inovátori usilujú o optimalizáciu hodnoty. Zvýšenie hodnoty novovytváraného objektu ako pomeru úžitku (uspokojenie potrieb) a spotreby (použitie zdrojov) možno dosiahnuť piatimi spôsobmi (obr.2).

$$\frac{\text{Uspokojenie potrieb}}{\text{Použitie zdrojov}} = \frac{\uparrow\uparrow\uparrow}{\uparrow} \text{ alebo } \frac{\uparrow\uparrow}{=} \text{ alebo } \frac{\uparrow}{\downarrow} \text{ alebo } \frac{=}{\downarrow\downarrow} \text{ alebo } \frac{\downarrow}{\downarrow\downarrow\downarrow}$$

Obr.2.: Spôsoby dosiahnutia zvýšenia hodnoty

Uvedené vnímanie hodnoty (podrobný výklad viď (5, 14)). umožní myslieť v reláciách hodnotového manažmentu a v jeho ideovom rámci popísať postup riešenia inovačných projektov. Preukázať dosiahnutie zvýšenia hodnoty je možné, na základe porovnania existujúceho a novo navrhovaného riešenia (riešení), prostredníctvom metód viackriteriálneho hodnotenia variantov. Konkrétne metódy pre takého hodnotenie je možné nájsť v príručke hodnotovej analýzy (10, 11).

Aplikácie hodnotového manažmentu a metodika TRIZ získajú výnimočnú dôležitosť najmä v prípade, keď budú používané v kombinácii s nasledovnými pokročilými nástrojmi podpory inovačného procesu:

1. Metóda QFD (Quality Function Deployment) a jej modifikácie, ktoré predstavujú výkonný nástroj pre skúmanie interakcií medzi rôznymi účastníkmi vývojového procesu. Hlavným prínosom týchto metód je fakt, že poskytujú všeobecnú štruktúru, v rámci ktorej môže prebiehať diskusia medzi členmi tímu rôznych profesií. Poskytujú spoločný jazyk a systematický mechanizmus pre skúmanie a riešenie mnohých typických otázok/problémov.
2. Známe systémy počítačovej podpory (CAx – Computer aided ...), ktoré umožňujú simulácie, spoločné skúmanie navrhovaných koncepcií a urýchľujú vlastný vývojový proces.
3. High technológie, ktoré poskytujú zhotovenie fyzických modelov navrhnutých konceptov vo veľmi krátkom čase, čo urýchľuje celý vývojový proces. Príkladom takýchto technológií sú napríklad: Rapid Prototyping, Rapid Tooling, Reverse Engineering a podobne (2).

Čo je dobré vedieť o realizácii inovačných projektov

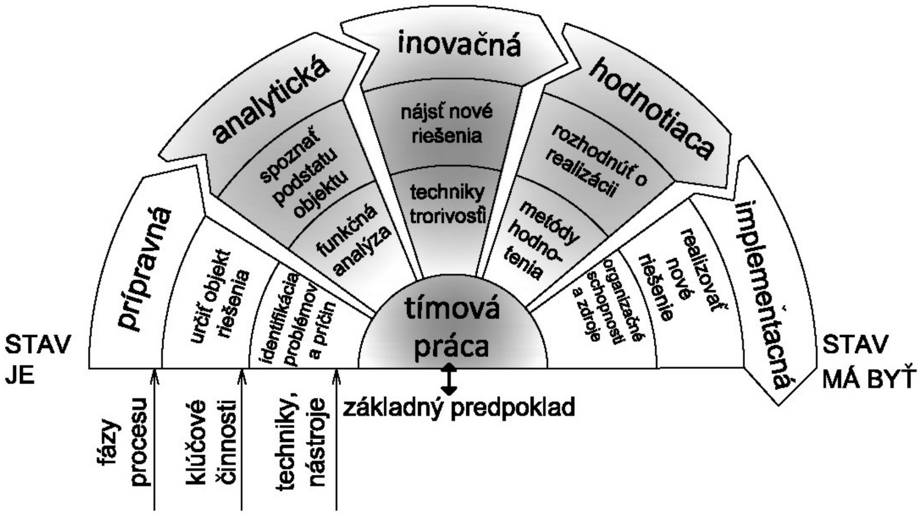
Proces riešenia úlohy formou inovačného projektu predpokladá, že v súlade so strategickými zámermi je vytýčený cieľ a prostriedky na jeho realizáciu. Je ustanovený riešiteľský tím, ktorý prostredníctvom prvkov procesu inovovania (riadený inovačný proces) usiluje o dosiahnutie vytýčeného cieľa. Previazanosť prvkov ilustruje obr.3.

Na prvý pohľad sa môže zdať, že popísaný proces inovovania je jednoduchý a racionálne mysliacimi ľuďmi vždy dodržiavaný. Prax tomu nenasvedčuje. I keď logika postupu býva dodržaná, väčšinou riešiteľské tímy podcenia prípravnú fázu, nestrácajú čas ani hĺbkovými analýzami (v analytickej fáze) a snažia sa čo najskôr vymyslieť nové riešenie.

Vzhľadom na tieto skúsenosti, sú v nasledovnom popísané aktivity, ktoré musia byť realizované najmä v prvých dvoch fázach procesu, ak má byť pripravená pôda pre vymýšľanie nových riešení.

Fazy procesu	**Przygotowawcza**	**Analityczna**	**Innowacyjna**	**Oceniająca**	**Wdrożeniowa**
Kluczowe działania	Określić objekt rozwiązawania	Zapoznać się z istotą objektu	Zaleźć nowe rozwiązania	Podjąś decyzję o realizacji	Realizować nowe rozwiązanie
Techniki, instrumenty	Identyfikacja problemów i przyczyn	Analiza funkcyjna	Techniki twórczości	Metody oceny	Zdolności organizacyjne i środki
Założenie podstawowe	Praca zespołowa				

Stan jest → Stan powinno być



Obr.3.: Previazanosť prvkov procesu inovovania

Prípravná fáza

Súčasťou prípravnej fázy je dôsledná príprava potrebných informácií. Vždy je potrebné dôkladne si ujasniť, čo je objektom riešenia. Objektom riešenia môže byť čokoľvek, čo je výsledkom ľudského snaženia – sú to produkty ľudskej práce (výrobok, služby, procesy, systémy, vzťahy). Objektom riešenia môže byť tiež ktorýkoľvek z činiteľov výrobného procesu (výrobok, surovina, technológia, stroj, energia, pracovná sila, organizácia). Signálom potenciálnej inovácie najčastejšie býva problém, ktorý zároveň iniciuje zadanie riešenia. Objektom riešenia má byť príčina problému, nie dôsledok. Z toho dôvodu je potrebné preskúmať celú škálu možných príčin. K zisťovaniu príčin môže slúžiť bežne používaný diagram príčin a následkov (Ishikawov diagram).

Nech už je objektom riešenia ktorýkoľvek z produktov ľudskej práce či výrobných činiteľov, prípravná fáza je určená k sústredeniu, spracovaniu a vyhodnoteniu dostupných informácií o objekte, ktorý má byť analyzovaný a následne navrhnuté jeho nové riešenia. Predpokladom efektívnej práce riešiteľského tímu je dôkladné poznanie a objektívna analýza poznatkov o súčasnom stave.

V prípravnej fáze riešenia inovačného projektu odporúčame realizovať nasledovné kroky:

1. Popis reálneho objektu ako systému.
2. Štúdium histórie objektu a substitútov.
3. Procesná analýza.
4. Intuitívne zistenie funkcií.
5. Generovanie a analýza požiadaviek na systém.
6. Komponentný model.
7. Štruktúrny model.

Čím viac relevantných informácií sa zistí a dokumentuje v prípravnej fáze riešenia inovačného projektu, tým efektívnejšia môže byť práca v nasledujúcich fázach riešenia projektu.

Analytická fáza

Analytická fáza je zameraná na vytvorenie modelu ideálnej funkčnosti objektu analýzy a na formulovanie zadania k realizácii tohto modelu. V tejto fáze je preferovaná funkčne-nákladová analýza, ktorá umožňuje:

- dôsledné skúmanie podstaty objektu,
- proces abstrakcie,
- transformáciu konkrétnej formy analyzovaného objektu do jeho všeobecnej, zastupiteľnej podoby pomocou súboru funkcií,
- skúmanie vymedzeného správania sa a vedľajších účinkov, teda funkcie objektu ako účelového systému,
- proces zovšeobecnenia problému definovaním funkcií, čím sa zámerne zatieňuje konkrétna podoba reálneho objektu, a tak sa zabráni vzniku nepriaznivých dôsledkov funkčnej fixácie,
- odstraňovanie stereotypov myslenia a všetky ďalšie predstavy zväzujúce tvorivosť,
- identifikovať funkcie a zostaviť ich zoznam, usporiadať funkcie, charakterizovať funkcie, zostaviť ich do hierarchického usporiadania, hodnotiť funkcie.
- určiť náklady na funkciu (náklady na funkcie nemôžu byť presné a nespochybniteľné - slúžia pre získanie predstavy o nárokoch na spotrebu zdrojov konkrétneho technického riešenia).
- stanoviť kritické funkcie, ktoré budú predmetom riešenia projektu,
- názornú prezentáciu dosiahnutých výsledkov.

Dôsledným vyšetrovaním jednotlivých funkcií z hľadiska užitočnosti i z hľadiska nákladov dostávame informáciu, čo zmeniť, ktoré funkcie realizovať inak, ktorým smerom sa má uberať úsilie inovátora. Je tak pripravená pôda pre nasledovnú inovačnú fázu, v ktorej pomocou metód tvorivého myslenia sú vytvárané varianty nových riešení.

Inovačná fáza

Vstupom do inovačnej fáze je súpis kritických funkcií a dôkladné poznanie skúmaného objektu, ktorý je predmetom procesu inovovania. Cieľom práce tímu v tejto fáze je vytvoriť námety na nové riešenie. To je zviazané s nasledovnými aktivitami:

- zhrnutie poznatkov z predchádzajúcich fáz riešenia,
- klasifikácia jednotlivých zadaní a výber spôsobov riešenia,
- vyhľadávanie námetov na nové riešenia,
- formulovanie komplexu návrhov na zdokonalenie objektu.

Postup riešenia úloh v tejto fáze je výrazne ovplyvňovaný zložitosťou riešeného problému, získaným poznaním v predchádzajúcich fázach, schopnosťou a zručnosťou uplatnenia techník tvorivosti a zručnosťou vedenia tímov.

Vytváranie nových riešení je zložitým procesom tvorivého myslenia a kritického hodnotenia. Vychádza z jednoznačne definovaných funkcií a je snaha vygenerovať maximum námetov na riešenie. Námetom sa rozumie myšlienka, alebo len naznačená predstava riešenia. Návrhom sa rozumie prepracovaná a vyhodnotená možnosť riešenia. Je mnoho metód vytvárania a zbierania nápadov. Nie všetky z nich sú však vhodné pre všetky situácie. Môžu byť rozdelené podľa množstva a jedinečnosti nápadov, ktoré ich aplikácia produkuje. Najprv sa treba opýtať, aký typ nápadov chceme zbierať.

Najjednoduchšou metódou je zozbierať už existujúce nápady. Toto je možné zbieraním z dokumentov, od osôb pomocou rozhovorov, dotazníkov, prieskumom literatúry, alebo na stretnutiach, kde sa ľudia delia o nápady za pomoci moderátora. Ak sa z jednoduchých metód nevytvoria nové uspokojujúce návrhy, je možné pristúpiť ku zložitejším tvorivým technikám.

Je mnoho takých techník, ktoré sú navrhnuté na obídenie negatívneho myslenia a odkrývanie nepreskúmaných oblastí stimulovaním tvorivého myslenia. Sú navrhnuté na potlačenie zvykových, vnemových, predstavových, kultúrnych a emocionálnych blokov, ktoré brzdia tvorivosť. Tímová práca, techniky tvorivosti a zručnosť vedenia tímov sú univerzálne nástroje pre riešenie úloh. Nie sú viazané na žiadnu špeciálnu metodiku.

Hodnotiaca fáza

Je prirodzenou fázou každého racionálneho procesu. Pri hodnotení výsledkov inovačnej fázy treba vychádzať z vopred určených kritérií pre posúdenie vhodnosti nápadov a námetov na konkrétne riešenia, ktoré boli dosiaľ vygenerované. V súlade s tým, ako postupuje proces od všeobecného ku konkrétnemu, uplatňujú sa i rozdielne nástroje pre kvalifikované rozhodovanie o prijatí či odmietnutí navrhovaných variantov.

Implementačná fáza

Implementačná fáza je prirodzenou zložkou racionálneho pracovného postupu. V tomto prípade treba ňou rozumieť záverečnú fázu riešenia inovačného projektu. V priebehu tejto fázy sa kladie dôraz na sumarizáciu zistení a ich prezentáciu. Je vypracovaná detailná správa, ktorá popisuje výsledky všetkých predchádzajúcich fáz riešenia projektu.

Daná správa je odovzdaná zadávateľovi projektu pre potreby jeho ďalšieho využitia. V prípade prijatia navrhovaného riešenia daná správa je rozhodujúcim vstupom pre realizáciu samotnej inovácie.

Pri inovačných projektoch obyčajne nasledujú fázy za sebou v sekvenciách. Je to cyklický proces. V praxi je často nutné vrátiť sa do predtým ukončenej fázy pre viac informácií, alebo vykonať dodatočnú prácu nutnú pre vykonanie rozhodnutia. Proces inovovania využíva veľké množstvo metód a ich kombinácií. Štruktúru najviac využívaných metód pre túto oblasť poskytujú metodiky hodnotového manažmentu.

Inovácie sú viditeľnými výsledkami neviditeľných vonkajších procesov, ktoré musia byť riadené. Vzťah ľudia k cieľom a k zmenám má značný vplyv na dosiahnutie výsledku vo forme výborných výsledkov práce. Zmena správania sa ľudí, nie je jednoduchá, ale možná. Uvedomenie si neustálej dynamiky zmien je východiskovým bodom pre vznik inovácií, na čo musí reagovať organizácia zmenou procesov i produktom. Od manažérov sa očakáva riadenie týchto procesov, od pracovníkov sa očakáva ochota zapojiť sa do procesov vytvárania nových vecí.

Záver

Inovácie sú viditeľnými výsledkami neviditeľných vonkajších procesov, ktoré musia byť riadené. Vzťah ľudia k cieľom a k zmenám má značný vplyv na dosiahnutie výsledku vo forme výborných výsledkov práce. Zmena správania sa ľudí, nie je jednoduchá, ale možná. Uvedomenie si neustálej dynamiky zmien je východiskovým bodom pre vznik inovácií, na čo musí reagovať organizácia zmenou procesov i produktom. Od manažérov sa očakáva riadenie týchto procesov, od pracovníkov sa očakáva ochota zapojiť sa do procesov vytvárania nových vecí.

Príspevok tiež poukazuje na skutočnosť, že nemožno budovať novodobé systémy riadenia bez využívania teoretických základov a metodických nástrojov podporujúcich vznik inovácii.

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2

CONDUCIVE SYSTEM ENVIRONMENT FOR MANUFACTURING ORGANIZATIONS

SYSTÉMOVÉ OKOLIE PODPORUJÚCE VÝROBNÉ ORGANIZÁCIE

Chapter 2.1.

OCCUPATIONAL SAFETY MANAGEMENT IN INDUSTRIAL COMPANIES IN VIEW OF LEGAL REGULATIONS BINDING IN POLAND AFTER ITS ACCESSION TO THE EUROPEAN STRUCTURES

RIADENIE BEZPEČNOSTI PRÁCE V PRIEMYSELNÝCH PODNIKOCH Z HĽADISKA PRÁVNYCH PREDPISOV ZÁVÄZNÝCH V POĽSKEJ REPUBLIKE PO VSTUPE DO EURÓPSKYCH ŠTRUKTÚR

Teresa LIS[1], Marek MATLAK[2], Wioletta OCIECZEK[3]

Key words: workplace safety, accident rate, labour law

Abstract
This article presents systemic solutions and related problems concerning occupational safety and hygiene in Polish industrial companies. Special focus is put on the rate of accidents at work and the role of clusters in the development of occupational safety and hygiene.

[1]Ph.D. Eng., associate professor of the Silesian University of Technology, Silesian University of Technology, Faculty of Mechanical Engineering and Mechatronics, Chair of Management and Computer Science, 40-019 Katowice, Poland
[2]Master, Lawyer at Law Office - Attorneys & Counselors at Law - FRANKIEWICZ&KAPELA Law Chamber - Kraków, Poland.
Chairman of the Supervisory Board PGP S.A.
[3] Ph.D. Silesian University of Technilogy, Silesian University of Technology, Faculty of Mechanical Engineering and Mechatronics, Chair of Management and Computer Science, 40-019 Katowice, Poland

1. Introduction

The views on occupational safety vary depending on the transformation of management conditions and the development of science and technology. Within the last few years, the interest in safety management has increased due to the growing awareness that safe work implies larger profit for the company. The implementation of market economy system and the resulting competition stimulate economic management, and the role of economic stimuli connected with occupational safety becomes more and more important. In the current approach, occupational safety is not limited to prevention of employees' injuries and profession-related disorders, but also refers to all incidents resulting in damages, e.g. breakdowns, stoppages, environmental pollution.

Currently, there is a common belief that appropriate occupational safety management is the most effective measure to ensure occupational safety and should constitute an inherent part of company management.

Occupational safety management includes aspects of general management related to the establishment and implementation of occupational safety policy, within which the following issues can be distinguished: the application of preventive measures as the fundamental aim of occupational safety management system, prevention of profession-related risk on the basis of risk assessment, preparation of documents facilitating the measures related to occupational safety, implementation of the principle of „constant improvement" on the basis of the assessment of risk level and the achieved indicators (1).

This study presents systemic elements influencing the implementation of occupational safety management, the applied occupational safety indicators and their use in the establishment of a diversified interest rate of accident insurance, as well as a safety level analysis in companies within various branches of industry.

2. Elements of systemic management of occupational safety

The problems related to occupational safety have been solved throughout centuries. It was not until the end of the 20th century that work safety started to be approached systemically.

Effective occupational safety management depends on harmonious coexistence of a series of systems, such as: research and certification system, legal measures, scientific and educational measures and economic measures (Fig.1).

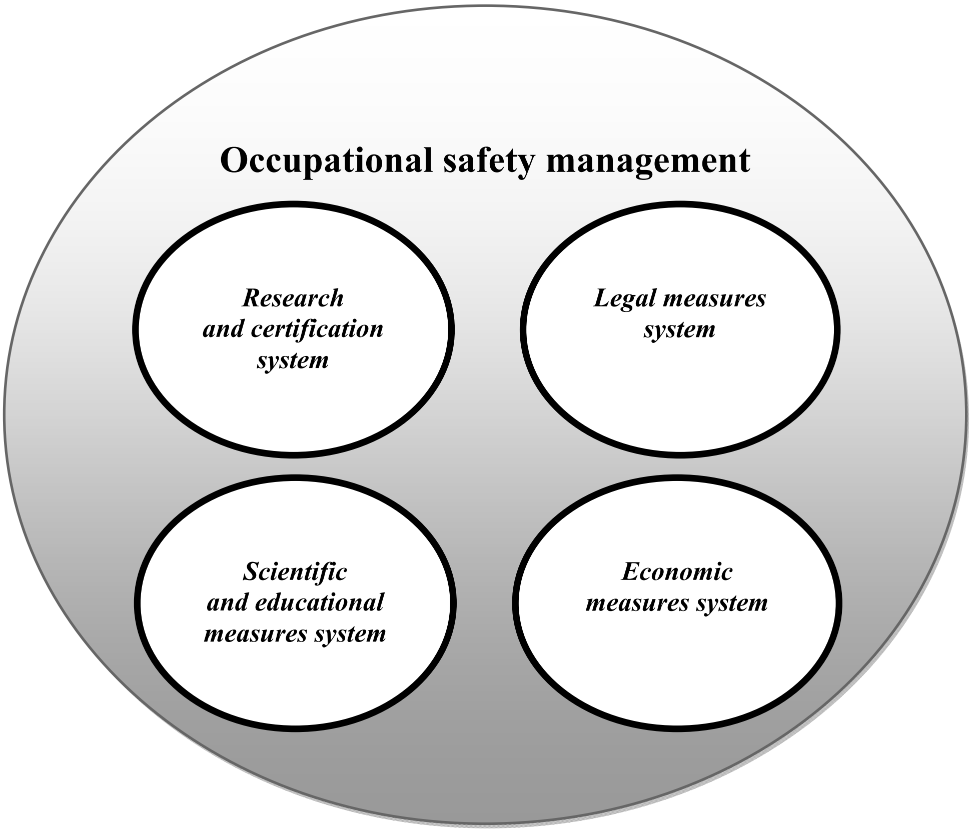

Fig.1.: Occupational safety management and cooperating systems, (own study)

Research and certification system is a system operating on the European Union level with the aim to ensure free flow of goods in the Economic Community area, characterized by certain safety features concerning the use of these goods. The aims of the research and certification system are:

- harmonization of technical requirements and procedures (technical harmonization directive),
- setting fundamental safety requirements for individual product categories,

- harmonization of the existing technical standards and participation in the process of establishment and harmonization of European technical norms,
- establishment of assessment procedures concerning the coherence of products with fundamental requirements (CE marking),
- setting the requirements for authorized laboratories responsible for the activities provided for in the conformity procedures,
- setting the requirements for certification units (notified).

Legal measures system aims at the establishment and implementation of legal requirements ensuring the citizens of individual countries life and health protection and safe work conditions. This system operates differently in every European Union country. In Poland, the most important legal act in the scope of occupational safety is the Constitution of the Republic of Poland and the act issued on the basis thereof – the Labour Code. In referrence to the Labour Code (most frequently to its Section 10) more datailed acts and ordinances are issued, aiming at the establishment of safe and hygienig occupational conditions, enabling the state to supervise them and to control the implementation of the EU directive into the national law.

Scientific and educational measures system includes education and scientific work.

Education should include all levels of knowledge acquisition through the introduction of issues concerning occupational safety and hygiene as well as ergonomics into the curricula. Moreover, some forms of post-school education should be taken into consideration in this scope (compulsory and performance improvement trainings). Especially for this area, the forms of work safety trainings should be diversified, including more and more broad use of e-learning (2,3).

Scientific work, i.e. research and development, grants, strategic programmes, budget financing aiming at conducting research and implementation of work methods, technques, technology, enabling an improved protection of employee's life and health (including group safety measures and individual safety measures as well as the establishment of highest permissible concentration and intensity).

Economic measures system. This system may encompass the operation of economic incentives connected with the amount of customs duties, credit interest rate, taxation and the amount of the so called accident insurance.
The system of credit measures is a preferential interest rate of credits dedicated to the improvement of work conditions (purchase of safer technology, machines, devices, etc.).

Customs measures system is the customs policy of the state, diversification of customs duties for goods imported from abroad in view of the dangers which they may pose and the required certificates, as well as goods serving to protect and save human life.

Tax measures system can include allowances for employers, who incurred expenditures for the purpose of occupational safety and hygiene, tax allowances for producers of certain goods serving the purpose of life or health protection.

Unfortunately, in Poland there is no system of credit, customs and tax economic measures. In 2003 there have been some changes in the standards for setting the interest rate of installments for insurance against work accidents and profession-related disorders (4,5) (accident insurance), which results in diversified accident insurance amounts. The interset rate of accident insurance depends on the indicators connected with occupational environment safety and occupational safety (rate of accidents). These are frequency indicators which depend on the number of employees working in conditions of exceeded hygiene norms, number of employees who sufferred from accidents at work, number of employees who sufferred from severe or fatal accident at work and the number of identified profession-related disorders.

On the basis of these indicators partial risk categories are established, as well as the risk category for a group of activity (production branch) and individually for the company. If the company reaches a lower risk category (higher safety level) than the set category for a given group of activity, the interest rate of the accident insurance installment is corrected with the use of the factor lover than 1. In case if the company reaches a higher risk category (lower safety level) than the category set for a given group of activity, the interest rate of the accident insurance installment is corrected with the use of a factor higher than 1. For example: a company „production of metal and metal goods" hires 300 employees of a monthly gross income of PLN 3 000 (EUR 750). The risk category set starting from 1.04.2009 for this group of activity is category no 9 and the interest rate of the accident insurance installment amounts to 2%. If a company separately acquired the same category, the yearly sum allotted to accident insurance amounts to PLN 216,000 (EUR 54,000).

If the risk category set individually for a company is by 4 categories lower than the risk category set for its group of activity, then the corrective factor amounts to 0.7, and thus the interest rate of the installment for accident insurance amounts to 1.4% - the yearly sum for this insurance amounts to PLN 151,200 (EUR 37,750) (a saving of PLN 64,800 (EUR 16,200) in a year). However, if a risk category set individually for a company is, for example, by 4 categories higher than the risk category set for its group of activity, then the corrective factor amounts to 1.3, and thus the interest rate of the installment for accident insurance amounts to 2.6% - yearly sum allotted to this insurance amounts to PLN 280,800 (EUR 70,200).

3. Work safety factors

The knowledge on accident rate factors can be used to compare the level of safety between particular branches of business, companies and periods of time. These factors also have informative and motivational function in the process of undertaking measures to reduce the accident rate. Informing employees on own accident rate, comparing it between departments with the rates of other companies is one of the elements to stimulate safety awareness and develop occupational safety culture.

The most popular indicators defining the occupational safety level are the so called accident rate indicators - the indicator of accident frequency and the indicator of accident gravity, defined by the following formulas:

$$W_{cz} = \frac{l_w}{U} \cdot 1000 \tag{1}$$

$$C_W = \frac{d_s}{P_1} \tag{2}$$

where:

W_{cz}	–	work accident rate indicator,
C_W	–	work accident gravity indicator,
U	–	number of employees (insured),
P_1	–	number of employees, who suffered from accidents at work,
l_w	–	number of accidents at work,
d_s	–	sum of lost days (absences) due to accidents at work.

Moreover, according to the ordinance on the diversification of accident insurance interest rate, indicators of occupational safety level influencing the establishment of risk category for the payer of the contributions for accident insurance are as follows:

$$W_1 = \frac{P_1}{U} \cdot 1000 \tag{3}$$

$$W_2 = \frac{P_2}{U} \cdot 1000 \tag{4}$$

$$W_3 = \frac{P_3}{U} \cdot 1000 \tag{5}$$

where:

P2	–	*number of employees, who suffered from fatal or severe accidents at work,*
P3	–	*number of people employed in dangerous conditions, which are present in situation when the highest permissible level of concentration and intensity of health damaging factors in the work environment has been exceeded.*

An accident at work is a sudden incident causing an injury of the person involved, resulting from an external cause due to work:

- during or in connection with conducting regular work activities or carrying out superior's orders,
- during or in connection with conducting work activities lying within the interest of the company, even without superior's order,
- during the time when the employee remains at the disposal of the employer.

The following circumstances are the prerequisite to qualify the accident as equal with accident at work:

- during business trips, unless the accident was caused by the employee's behaviour which was not related to the performance of tasks entrusted to him or her,
- during a training in the scope of common self-defense,
- during the performance of tasks commissioned by the trade union organisation operating within the employer's company.

An accident is considered as severe work accident, if it results in severe body injuries, such as: loss of sight, hearing, speech, fertility or other body injuries or disorder of health, disturbing the basic function of the organism, as well as a terminal disease or a life threatening disease, permanent psychological disaese, total or partial inability to work in the given profession or a permanent, substantial disfigure or deformation of the body.

An accident is considered as fatal accident at work, if it results in death within 6 months upon the accident date.

Accidents are complex incidents. Their occurrence is a result of a combination of technical, environmental, human and organisational factors.

4. Occupational safety level in companies in chosen lines of bussines

The assessment of work safety level in chosen lines of business in the Polish industrial sector requires a reference to the number of people employed according to the systematics of the Polish Classification of Business Activity (PKD) and the publication of the Central Statistical Office (GUS). The last full data published by GUS refer to the state as of December 12, 2008, when there were around 14 million of people employed in Poland. In the "industrial processing" sector in Poland there are around 2.7 million people employed, which constitutes around 19.3% of the total number of the employed.

Industrial processing, both concerning the number of employed and the number of work accidents, scores on top of the classification. In 2008, around 41 thousand people injured were registered in this sector, and in 2009 there were around 30.5 thousand injured in work accidents (Table 1). The sector employs around 19.3% of the total number of employees in Poland, whereas when comparing the numbers of people injured, in 2008 the percentage constituted over 39% of the total number of injured and in 2009 over 35%.

Also the indicators presented in Table 2 inform on the frequeny of certain accidents. In average, there are 7.44 people registered as injured in accidents at work in Poland for each 1000 of employees. Comparing this number to the analogous indicator referring to industrial processing (15.18) we can conclude that employees in this sector are subject to twice as many work accidents as the national average. The situation is even more alarming in the mining sector (17.10) and metal industry sector (18.41). Taking under consideration the above, the textile industry (6.10) seems to be the sector of economy where work conditions are much safer.

The accidents' statistics is inseparably connected with the information on how severe the work accident actually was. Individual indicators presented in Table 1 and 2 contain this information. Accidents are classified according to their gravity, taking under consideration the number of days of absence, or according to the definitions of severe and fatal accident presented above (any other accident is the so called minor accident). The average rate of gravity of accidents at work in Poland varies between 34-35 days of absence falling on the recovery of one person injured. In this respect, the industrial processing sector stays within the national average numbers, whereas in case of individual subsectors some major deviations are visible.

This situation refers to e.g. metal industry (around 36 days of absence) and the metal production sector falling within the metal industry, where the indicator grows to ca. 39. It is also important to notice that the mining industry is currently in a very bad situation – every employee injured in an accident at work spends in average around 60 days on sick leave. This situation in the minng industry can only be compared to the construction sector, where a similarly high rate of gravity of accidents at work is observed.

The problems connected with ensuring occupational safety in industry in Poland are also evident when looking at the values of the frequency indicators for minor, severe and fatal accidents presented in Table 2. In case of industrial processing, a twice as high frequency of minor injuries has been recorded (15.00) in reference to the national average (7.34), and similarly in case of severe injuries (0.14 and 0.06 respectively). In case of fatal accidents, the indicator characteristic for industrial processing sector.

Table 1.

Employees injured in work accidents in Poland in 2008, 2009.
Own study based on (6)

Table 2.
Work accidents frequency indicators per 1000 employees in Poland in 2008. Own study based on (6)

Indicator	Poland	Industrial processing	Mining industry	Metal industry	Food industry	Textile industry
Total number of injured	7.44	15.18	17.10	18.41	15.59	6.10
Minor accidents	7.34	15.00	16.79	18.17	15.45	6.03
Severe accidents	0.06	0.14	0.14	0.19	0.10	0.05
Fatal accidents	0.037	0.036	0.170	0.050	0.046	0.012

(0.036) remains at the national average level (0.037). Unfortunately, similarly to the case of the indicator of accident gravity, especially the mining and metal industries exceed the national average mostly in the number of severe and fatal accidents. In the metal industry a three times higher number of severe accidents was registered (0.19) than the Polish average (0.06), whereas in the mining industry a four times higher frequency of fatal accidents was registered (0.170) in comparison to national average (0.037).

The accidents statistics presented above concerning chosen metal industry sectors indicate that the level of danger in industrial production is relatively high. It is obvious that the global perspective of the accidents statistics can be insufficient to establish priority measures in particular industry plants, yet the business line statistics allows for setting general directions for improvement in individual sectors. For example, in food industry and textile industry the pressure from people responsible for the establishment of occupational safety and hygiene policy should be directed towards the reduction of accidents, whereas in heavy industry (mining, metal industry) in the first phase it should be directed towards the reduction of the gravity of injuries in accidents at work and then towards the reduction of the accidents as such (6).

5. Legal factors of occupational safety management systems and requirements and guidelines resulting from national and international standards

5.1. National regulations

Work safety in companies in Poland, regardless of the volume of production or employment, has a vital position in the legal system binding on the territory of the Member States and the whole European Union.

The importance of this issue is even strongly underlined by the provisions concerning abiding by occupational safety and hygiene requirements in the act placed on top of the hierarchy of the sources of law in Poland and the Treaties establishing the European Economic Community – the so called Treaties of Rome – as well as the European Union Directives.

a) Occupational safety in the Constitution of the Republic of Poland

The Constitution as a primary act in the legal system of the Republic of Poland is the fundamental source of law. Article 24 of the Constitution of the Republic of Poland of 2 April 1997 provides that: *Work underlies the protection of the Republic of Poland. The state supervises the conditions of work.* In the quoted article of the Constitution of the Republic of Poland the Legislator included the fundamental standard for work conditions protection, which imposes on law enacting bodies the obligation to maintain and ensure safe and hygienic work conditions, fair salary and legal protection in case of an infringement of the provisions of the labour code (7).

Article 66 of the Constitution of the Republic of Poland provides that: *Everyone has the right to safe and hygienic work conditions. The citizen's* *right to life and health protection, also during work, has been included in the legal act of the highest rank; the right to safe work conditions is also guaranteed in the Constitution of the Republic of Poland for everyone, who performs work, irrespective of the legal basis for its performance. As a result, the constitutional protection covers not only people employed on the basis of an employment contract, but every citizen performing work on any other legal basis. The implementation of the constitutional guarantee is expressed in articles 304 et seq. of the labour code, which provide for the application of occupational safety nad hygiene regulations also in respect of people performing work on the basis of an agreement on commissioned work or an agreement for specific task. (...) Nonetheless, it has to be admitted that the legal direction adopted by the Polish legislator in respect of labour protection doeas not provide any basis for the assumption on a possibility of an infringement of constitutional guarantees. On the contrary, the hitherto legislation indicates that we are consistently harmonizing the Polish work protection law with the requirements of international law and European Union law (8).*

The realization of the above mentioned rightand the specification of employer's and employees' obligations at work are provided for in an act of lower rank in comparison to the Constitution, that is the act of 26 June 1974 – Labour Code (unified text: Journal of Laws of 1998 no 21, item 94 as amended).

b) Occupational safety in the Polish labour code

Polish experience and legal doctrine in the scope of enacting and application of labour law stresses the importance of the protection of work performed by employees and indulges in a relatively profound analysis of the effectiveness of implementation of the aforementioned standards.

The basic labour code regulations in the scope of occupational safety are placed in section 9 of the Labour Code concerning occupational safety and hygiene, in section 7 in the protection of women work and in section 9 on the protection of young people at work.

Article 9 of the Polish Labour Code, for that matter, indicates other sources of labour regulations, especially the prescriptive agreements concluded between social partners, i.e. collective labour agreements and other collective agreements, for example internal company acts enacted in form of work regulations and statutes.
According to the provisions of Article 207 et seq. of the Labour Code, the main duty of the employer towards the employees is to ensure occupational safety and hygiene in the workplace managed by the employer. From January 18, 2009, that is from the moment when the amendment of the Labour Code (Journal of Laws no 223, item 1460) entered into force, the scope of personal responsibility of the employer for the state of occupational safety and hygiene in the workplace has been significantly broadened. The responsibility of the employer is not reduced by the obligation of the employees to abide by the standards (article 211 of the Labour Code), nor by the fact that conducting the tasks of the safety and hygiene services is entrusted to specialists from outside the workplace due to the lack of competent employees (9).

According to the provisions of the labour code, the Employer is obliged to improve the existing employees' health and life protection level according to the changing work conditions, ensure the development of common preventive policy against accidents at work and profession-related disorders. This policy has to include not only technical issues, organizational matters and work conditions, but also social relations and the influence of work environment. All measures taken by the employer in the scope of work safety and hygiene cannot in any way burden the employees (10).

According to the content of the provisions of the labour code mentioned above, the employer is obliged to guarantee to its employees the freedom of undertaking measures aiming at the avoidance of direct danger to their life and health, even without consulting their supervisors.

The above mentioned provision guarantees that the employees, who undertook such measures without neglecting their duties, will not suffer from negative consequences of such measures aiming at the reduction of negative results having impact on them at the workplace.

The above regulations constitute the fulfilment of the so called educative function of the labour law (10).

The legislator in the whole section 10 (of the Labour Code – author's note) basically tries to implement the assumption that the addressees of the provisions of this section are the employer and the employees. The aforementioned assumption has several exceptions, not only due to the necessity to establish numerous authorizations to enact executory provisions of law and the existence (establishment) of entities and bodies, such as people who manage the employees, work safety and hygiene services of commissions, with the help of which the employer realizes its obligations. The provisions also impose certain obligations on the bodies supervising certain employers, but also producers, importers, distributors or other suppliers, state sanitary inspection (...)(10).

c) Occupational safety in Polish executory provisions

A particularly important complement of the Labour Code provisions in the scope of work safety and hygiene is, among others, the ordinance of the Minister of Work and Social Policy of September 26, 1997 on the general provisions concerning occupational safety and hygiene issued on the basis of article 237 of the labour code (10).

The Ordinance quoted above provides for general binding standards of occupational safety and hygiene in workplaces, especially concerning: 1) buildings, rooms and workplace area, 2) work processes, 3) hygiene and sanitary rooms and devices.

5.2. International regulations

a) Occupational safety in the European Union law

The changes in the scope of occupational safety and hygiene introduced in the Polish Labour Code and the executory ordinances result from the fulfilment of obligations imposed on the governments and legislatory bodies of the Mamber States, and consisting in harmionization of the legal provisions of the Member States with the European Union Standards. The obligation to adjust the Polish provisions of law to the requirements of the European Union law results from *Article 118a of the Treaty Establishing the European Economic Community – the so called Treaties of Rome – stating that the Council is going to introduce in form of Directives minimum requirements stimulating to undertake measures, especially in the workplace, ensuring higher level of safety and health of employees. The Directive is a legal act having no equivalent in the Polish legal system. It is a legal act imposing the obligation to implement the content included therein into national law in form or legal acts binding within the given country (11).*

In the scope of work safety and hygiene the Directives of the European Union Council (European Community), which refer to the protection of work and care for occupational safety and hygiene, are very important.
These are especially:

1. Directive of the Council of EEC 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvemetns in the safety and health of workers (Official Journal of the EC 1989 L 183/1-8) described as framework directive – article 16 of the above mentioned regulation is the basis for the adoption of detailed directives by the Council, and these are i.a. (11),
2. Directive of 30 November 1989 (89/654) concerning minimum safety and health requirements for the workplace
(Official Journal of the EC 1989 L 393/1),
3. Directive of 30 November 1989 (89/655) concerning the minimum safety and health requirements for the use of work equipment by workers at work (Official Journal of the EC 1989 L 393/13-17),
4. Directive of 30 November 1989 (89/656) on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace
(Official Journal of the EC 1989 L 393/18-28),
5. Directive of 29 May 1990 (90/269/EWG) on the minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers
(Official Journal of the EC 1990 L 156/9),

6. Directive of 28 June 1990 r. (90/270) on the minimum safety and health requirements for work with display screen equipment (Official Fournal of the EU 2007 L 156/14),
7. Directive of the Council of 28 June 1990 (90/394) on the protection of workers from the risks related to exposure to carcinogens at work (Official Journal of the EC 1990 L 196/1-7),
8. Directive of 26 November 1990 (90/679) on the protection of workers from risks related to exposure to biological agents at work (Official Journal of the EC 1990 L 374/1-12),
9. Directive of 24 June 1992 (92/57) on the implementation of minimum safety and health requirements at temporary or mobile construction sites (Official Journal of the EC 1992 L 245/6-22),
10. Directive of the Council (92/58) of 24 June 1992 on the minimum requirements for the provision of safety and/or health signs at work (Official Journal of the EC 1992 L 245/23-42),
11. Directive of 92/85/EEC of 19 October 1992 on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding (Official Journal of the EC 1992 L 348/1),
12. Directive of the Council 92/91/EEC of 3 November 1992 concerning the minimum requirements for improving the safety and health protection of workers in the mineral-extracting industries through drilling (Official Journal of the EC 1992 L 348/9-24),
13. Directive of the Council 92/104/EEC of 3 December 1992 on the minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extracting industries (Official Journal of the EC 1992 L 404/10-25),
14. Directive of the Council 93/103/EC of 23 November 1993 concerning the minimum safety and health requirements for work on board fishing vessels (Official Journal of the EC 1993 L 307/1-17),
15. Directive of the Council 98/24/EC z 7 kwietnia 1998 r. on the protection of the health and safety of workers from the risks related to chemical agents at work (Official Journal of the EC 1998 L 131/11-23),
16. Directive of 1999/92/EC (of the European Parliament and the Council) of 16 December 1999 on minimum requirements for improving the

safety and health protection of workers potentially at risk from explosive atmospheres
(Official Journal of the EC 2000 L 23/57-64) etc.

The category of directives concerning occupational safety and hygiene (especially due to the mode of their handover) include also the Directive of the Council 93/104/EC of 23 November 1993 concerning certain aspects of the organization of working time (Official Journal of the EC 1993 L 307/18-24) and Directive of the Council 94/33/EC of 22 June 1994 on the protection of young people at work (Official Journal of the EC 1994 L 216/12-20).

In the scope of safety management in industrial companies the so called Machine Directive (89/37/EC) plays a significant role – *addressed to producers and distributors of machines and safety elements (12).*
The discussed regulation sets tasks leading to the fulfilment of requirements in the scope of health and safety protection for new machines in order to eradicate trade barriers within the area of Europe and in order to guarantee the users and operators high level of safety and health protection. The above mentioned rule concerns machine production and the introduction of used devices and machines from third countries, from which the goods are introduced into the market within the customs area of the European Union.

The first version of the "Machine Directive" of the European Union Council of 1989 (89/392/EEC) was later subject to several amendments, whereas in 2006 the new, so called „New Machine Directive" (2006/42/EC), was issued and implemented into the Polish legal system by an Ordinance of the Minister of Economy of 21 October 2008 on substantial requirements for machines (13).

In the conclusions concerning the European directives mentioned above it is important to state that most of their content was implemented into the Polish legal system in the moment of the Polish accession to the European Union, i.a. through the provisions of the Labour Code and the relevant ordinances, especially the ordinance of the Minister of Labour and Social Policy concerning general provisions on occupational safety and hygiene of 26 September 1997 (14, 15).

b) Occupational safety in international agreements and conventions

The right to safe and hygienic work conditions is confirmed in the Constitution of the Republic of Poland. According to Article 66 par. 1, everyone has the right to safe and hygienic work conditions, yet the mode of implementation of this right and the obligations of the employer are provided for in the relevant act.

A similar approach is also visible in the European Social Charter ratified by Poland on 10 June 1997, constituting a document of the Council of Europe concerning social and economic rights of citizens, open for signing on 18 October 1961 in Turin. The provisions of this document ensure civil and political rights and freedoms without discrimination based on race, skin colour, sex, religion, political views, and national or social origin. The Charter guarantees also a number of rights and freedoms in the social sphere.

Moreover, Poland ratified a number of conventions of the International Labour Organization concerning the questions of occupational safety and hygiene.

These are:

1. Convention of 26 September 1906 respecting the Prohibition of the Use of White (Yellow) Phosphorus in Manufacture of Matches, Berne (Journal of Laws of 1922 no 19, item 159),
2. Convention of 19 November 1921 (no 13) concerning the use of White Lead in Painting, adopted as a project in Geneva
(Journal of Laws of 1925 no 54, item 382),
3. Convention no 62 concerning Safety Provisions in the Building Industry, adopted in Geneva on 23 June 1937
(Journal of Laws of 1951 no 11, item 83),
4. Convention no 81 concerning Labour Inspection in Industry and Commerce adopted in Geneva on 11 July 1947
(Journal of Laws of 1997 no 72, item 450),
5. Convention no 115 concerning the Protection of Workers against Ionising Radiations adopted in Geneva on 22 June 1960
(Journal of Laws of 1965 no 8, item 45),

6. Convention no 127 concerning the Maximum Permissible Weight to Be Carried by One Worker, adopted in Geneva on 28 June 1967 r. (Journal of Laws of 1973 no 25, item 142) (16).

According to the quoted international convention, the national system should encompass national tripartite advisory bodies or institutions responsible for occupational safety and hygiene issues; information and advisory services responsible for occupational safety and hygiene issues; ensuring trainings in occupational safety and hygiene; services in the scope of occupational safety and hygiene, according to national law and practice (17).

In reference to the questions discussed above, it can be concluded that the provisions of ratified international agreements are a source of law in Poland on the basis of the provisions of the Constitution of the Republic of Poland, which in its article 91 par. 2 provides that: *(...) International agreement ratified under the prior consent expressed in an act of law has precedence over the act, if the act's provisions are contradictory to the agreement (...).*

5.3. The analysis of the research and certification system of the work safety and hygiene management processes

The need for certification results from the necessity of a systemic approach to work safety and hygiene management, resulting from growing demands of potential and present employees interested in working in improved and safer conditions. The interest is also reflected in the measures aiming at the internationalization of standards in the scope of occupational safety management system, covering occupational safety, ergonomics, health protection and natural environment protection.

In the European Union the substantial legal act of significance for work safety and hygiene management is, as it was mentioned above, Directive 89/391/EEC on the introduction of measures to encourage improvements in safety and health of employees at work.

There are also numerous national and international legal acts covering the scope of operation of the management system for occupational safety and hygiene system. A detailed and comprehensive analysis of these acts goes far beyond the framework of this study, and the description below is merely an attempt to systematize information in the discussed scope. Generally, occupational safety and hygiene policy should encompass the obligation of the company to prevent accidents at work and profession-related disorders, aiming at constant improvement of occupational safety and hygiene, fulfilment of the legal requirements, constant improvement of measures in the scope of occupational safety and hygiene, ensuring relevant measures for the implementation of the policy and increase of employees' qualifications.

a) International standards
In 1996 the British Standard Institution (BSI) prepared the BS 8800 standard, constituting a compilation of guidelines facilitating efficient forecast and prevention of circumstances endangering employees with loss of health or life and counteraction against profession-related disorders. At present, the OHSAS 18001:2007 standard is binding on international scale, with its equivalent in the Polish PN-N-18001:2004 standard binding in Poland.

b) National standards
The interest of Polish entrepreneurs in a systemic approach towards occupational safety and hygiene started to develop in the early 90s. At that time, the companies with developed quality management systems according to the ISO 9000 standards and environmental management systems according to ISO 14000 standards were searching for the possibilities to include issues connected with occupational safety and hygiene in the systemic measures. In that period, company standards of systemic occupational safety and hygiene management were established in cooperation with Central Instutute for Labour Protection and National Labour Inspection, for example in the Częstochowa Smalting Plant.

In 1998, with significant support of the contemporary Ministry of Labour and Social Policy, the Polish Committee for Standardisation appointed the Problem-Related Commission for Standardisation no 276 for Work Safety and Hygiene Management Systems.

The aim of the Commission was to:

- prepare relevant requirements and recommendations for the establishment and implementation of occupational safety and hygiene management system in Polish companies,
- determine appropoiate terminology in the scope of occupational safety and hygiene.

The works of the Commission resulted in the establishment by the Polish Committee for Standardisation in 1999 of the first and fundamental Polish Standard concerning occupational safety and hygiene management systems entitled Occupational Safety and Hygiene Management Systems. Requirements (PN-N-18801:1999).

The aforementioned standard was one of the first standards in this scope established in Europe and it aroused vast interest of companies in the implementation of a systemic approach towards occupational safety and hygiene management.

Further works of the Problem-Related Commission for Standardisation no 276 have lead to the publication of further standards:
PN-N-18002:2000 Occupational Safety and Hygiene Management Systems. General guidelines for profession-related risk assessment and PN-N-18004:2001 Occupational Safety and Hygiene Management Systems.

The first of these two documents was the fulfuillmnent of employees' needs concerning the realization of one of the most important elements of occupational safety and hygiene management system – profession-related risk assessment and the implementation of measures aimed at its prevention and reduction.

The second standard gives practical guidelines supporting the implementation of systemic management of occupational safety and hygiene in a company.

Occupational safety and hygiene issues in Poland are most comprehensively regulated by the PN-N-18001:2004 standard. PN-N 18001 covers 20 areas of standard safety and hygiene management. These are, among others: accidents' monitoring, employees' trainings, individual protection measures, work hygiene and health protection, safe technology, occupational safety and hygiene promotion within the company, safety outside workplace, preparation of plans in case of a failure, internal control, etc. Proper identification of risk allows for the development of a control system and the use of proper preventive measures.

The PN-N-18001:2004 standard can be applied by organizations of different profiles of activity, irrespective of the activity type and the entity size. This standard is based on rules governing management systems, provided for in the ISO 9001:2000 standard, therefore they constitute jointly an integrated quality management and occupational safety and hygiene system.

The PN-N-18001:2004 standard "Occupational Safety and Hygiene Management Systems. Requirements" and the OHSAS 18001:2007 specification include guidelines concerning occupational safety and hygiene management system in the general company/organisation management. Both PN-N 18001:2004 and OHSAS 18001:2007 set the requirements concerning occupational safety and hygiene management system in order to enable the organisation the establishment of policy and aims in this scope. The PN-N 18001:2004 standard and OHSAS 18001:2007 differ only slightly. In the paragraph concerning profession-related risk assessment, the Polish PN-N 18001 standard does not explicitly impose on subcontractors, suppliers, and visitors of the organisation the obligation of risk assessment. Such obligation is imposed by OHSAS 18001. The PN-N 18001 includes requirements concerning trainings, and specifically the obligation to implement methods to motivate employees.

The differences between OHSAS 18001 and PN-N-18001 are slight and refer mostly to the approach to the issue of third persons remaining in the area of the company and the profession-related risk assessment at the workplace.

The requirements provided for by these documents (OHSAS 18001 and PN-N-18001 – author's note) *enable the organisation to formulate the policy and aims in the scope of occupational safety and hygiene in accordance with its needs, as well as an effective realization of such policy through achieving the adopted tasks. The PN-N-18001 standar and OHSAS 18001 standard constitute the basis for certification of the company management system in* *the scope of occupational safety and hygiene, similarly to ISO 9001in the scope of quality management and ISO 14001 in the scope of environmental management.*

They were prepared is such a way, that there is a possibility to integrate quality management systems, environmental management systems and occupational safety and hygiene management systems in practice. The certification concerning coherence with PN-N-18001 or OHSAS 18001 confirms that the company acts effectively and responsibly in the scope of life and health protection of its employees (18).

The Polish PN-N-18001:2004 standard is coherent with OHSAS 18001, which means that the occupational safety and hygiene management system which fulfils the requirements of PN-N-18001:2004 also fulfils the requirements of the OHSAS 18001:2007 specification.

The entity applying for certification concerning its coherence with PN-N-18001, can also acquire the certificate of coherence with OHSAS 18001 without the necessity to conduct an additional audit.

Benefits of the implementation of the management system according to PN-N-18001/ OHSAS 18001

- facilitation of organization (company) management, especially in the scope of fulfilment of legal requirements and other requirements of occupational safety and hygiene,
- identification of threats to the safety of the employees and rapid preventive measures, especially in the situation of changing conditions and range of production or services,
- engagement of all employees in ensuring occupational safety,
- reduction of the number of accidents and injuries at work,
- reduction of accident-related costs,
- reduction of disease-related absences,
- increase of trust in the organization and identification with the company,
- improvement of work conditions and thus increase of work efficiency,

- reduction of work costs and thus an increased positive impact on the economic results of the organization,
- increase in trust of customers, insurance companies and state control authorities,
- easier acquisition of subsidies for modernization investments,
- establishment of a positive image of the company in the market (18).

SCC – international occupational safety and hygiene management system

SCC (Safety Certificate Contractors) is an abbreviation referring to a safety, health and environmental management system for subcontractors, which can undergo a certification process.

The aim of the SCC standard is the assessment of occupational safety and hygiene in companies providing technical services, i.a. in the chemical line of business and in construction. The SCC certificate confirms that a company/organization has a responsible and professional approach to issues concerning occupational safety and hygiene (18).

SCC can be implemented in any organization/company, irrespective of the business line and company size.

SCC certificates are issued by the Work Safety and Hygiene Management Systems Certification Unit - TÜV Rheinland GmbH in Cologne. The Unit has a TGA accreditation (TGA –Trägergemeinschaft für Akkreditierung - German Association for Accreditation) marked with the number TGA-ZM-58-95-62.
Within the SCC certification procedure two types of certificates are offerred:

SCC - limited certification*
Within the limited certification the activities concerning safety and health protection as well as with environmental protection conducted directly at the workplace are assessed (SGU); the model is addressed to small companies (up to 35 employees, including the employees hired for definite period of time and apprentices, in the whole company).
*SCC** - unlimited certification*

Apart from the criteria provided in the paragraph on SCC, the assessment encompasses also the safety and health protection as well as environmental protection management system in a company. This certificate is addressed to companies which employ over 35 people, including the employees hired for definite period of time and apprentices, in the whole company. Companies employing more than 35 people, but also using subcontractors (agreements for specific task) to provide technical services, should obtain the SCC certificate**.*

Profits from SCC certification

A certified SCC system is a guarantee for the Contracting Party/Ordering Party that the subcontractors employed in large industrial companies will proceed according to the occupational safety and hygiene requirements binding in these companies.

Thanks to the comparable requirements systems concerning occupational safety and hygiene management, misunderstandings concerning work safety can be avoided.

There is a possibility to reduce the costs of both Parties, because the periods of failure-free operation are extended and cost-intensive audits conducted by the Ordering Parties are no longer required.

The periods of machine and devices stoppages due to subcontractor's fault is reduced.

Experience shows, that the increase of awareness concerning the importance of operational safety and hygiene among the employees leads to a reduction of the accident rate, and thus to a decrease in work costs and a significant increase of legal safety level.

The occupational safety and hygiene management systems are an effective measure supporting and developing the company's operation, provided that the implementation and the realization of the prescriptive demands by the employees on all levels of the certified entity is intentional.

However among the undeniable profits we should name not only those related to the identification of the entity, but also those connected with the guarantee, consisting in sustainable commitment to maintain a certain level of occupational safety and hygiene and ensure all interested parties about the professional, reliable and responsible approach of the entity to the question of health and life of its employees.

From the point of view of vital interests of the entity, the economic profits resulting from the certification are of utmost importance; this is due to the decrease in absences of employees resulting from the limited number of accidents at work and profession-related disorders, decrease in costs incurred due to accidents at work and profession-related disorders, minimization of the COPQ (Cost of Poor Quality) indicators, and thus an increase of work quality and efficiency, optimization of the safety level, which translates into the profit achieved by the company; the certified system is also an asset taken under consideration in the company valuation (19).

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Chapter 2.2.

THE EFFECTS OF CORPORATE SOCIAL RESPONSIBILITY BASED ON AN EXAMPLE OFSTEELWORKS

ÚČINKY SPOLOČENSKEJ ZODPOVEDNOSTI ZALOŽENÉ NA PRÍKLADE OCELIARNE

Wioletta OCIECZEK[1], Bożena GAJDZIK[2], Marzena KUCZYŃSKA-CHAŁADA[3], Marcin PILARCZYK[4]

Key words: corporate social responsibility, social reporting

Summary

The aim of the publication was to present the effects of corporate social responsibility based on an example of steelworks. As a case study steelworks ArcelorMittal was taken. The company is a part of global capital group – the world's producer of steel and steelworks products. The corporation realises activities of corporate social responsibility in order to implement ISO 26000 system. In 2008 the company published the first report on corporate responsibility. Its results are enclosed in practical part of this publication. In the theoretical part the key rules of corporate social responsibility are presented as well as the process of reporting.

[1] Ph.D. Silesian University of Technilogy, Silesian University of Technology, Faculty of Mechanical Engineering and Mechatronics, Chair of Management and Computer Science, 40-019 Katowice, Poland
[2] Ph.D. Eng. Silesian University of Technilogy, Silesi
an University of Technology, Faculty of Mechanical Engineering and Mechatronics, Chair of Management and Computer Science, 40-019 Katowice, Poland,
[3]Ph.D. Eng. Silesian University of Technilogy, Silesian University of Technology, Faculty of Mechanical Engineering and Mechatronics, Chair of Management and Computer Science, 40-019 Katowice, Poland,
[4] Master, Eng.Silesian University of Technilogy, Silesian University of Technology, Faculty of Mechanical Engineering and Mechatronics, Chair of Management and Computer Science, 40-019 Katowice, Poland

Entry

By the end of XXth century globalization and raise of competition had enlarged economical diversity of societies. More frequently societies suffered from negative consequences of unemployment, destroying environment, cultural differences as well as unethical companies activities. Organizations all over the world demanded working out and following the rules of ethical business and activities in favour of environment and societies. Thanks to their appeals some activities in factories were implemented. They are called social responsibility (1).

In the professional publications there are various definitions of a corporation that is social responsible. In general it is customary that corporate social responsibility goes over its typical economical, technical and legal conditions. Corporate social responsibility is a result of relations between corporations and their environment. In the conception of corporate social responsibility business mustn't be done if either the society or the environment suffers (2). To be a social responsible company means investing in human resources, environment protection and maintaining good relations with all groups of interests (3).

The conception of social responsibility was applied within European Union. The basic document describing this conception is "Green Paper for Promoting a European Framework for Corporate Social Responsibility". The document was approved in Brussels in July, 2001 by the European Committee. The *Green Paper* defines the frames of of corporate social responsibility on European scale. Companies which are social responsible create a new strategy and implement it into their activities on the market. They are aware of society and environment protection. The social responsibility, according to *Green Paper*, should become a part of strategic management of a company (4).

Poland, as a member of EU, promotes the rules of corporate social responsibility. Companies voluntarily implement these rules while dealing with their receivers: internal (employees) and external (local societies, contracting parties, co-operators, clients). The activities called corporate social responsibility are also realized in polish steelworks companies. Among these companies there is ArcelorMittal Poland SA. In the practical part of this publication the company's effects in the sphere of social responsibility are presented.

1. The scope of corporate social responsibility

In the economic practise there are two kinds of corporate social responsibility: internal and external. It is the result of company's activities which are divided into internal and external. The parties are various. As it comes to internal parties these are the employees and their families. The companies that are focused on corporate social responsibility apply new qualities and rules (ethical rules, equality of rights, respect towards other people). The employers concentrate on creating safe working conditions. In this process the employees of a production department take part in it as well. These workers are aware and respect the safety rules. The companies focused on human resources believe that people are the major capital of business. One of the basic rules of the conception of human resource management is improving the employees' potential and treating them as an integral part of the company's development process. Te employees are encouraged to study and develop (5). The employees are expected to implement changes (innovative solutions) in particular departments of the company. The idea of the changes is to exchange present solutions by new, better ones. Each improvement of the company's function simplifies the working process while the work itself becomes safer (6) .

As it comes to external parties they vary. First is environment management which is realized as a part of dynamic model of environment protection that focus on preventing production of pollution and following the strategy of Clean Production (7). Second sphere is the local society. The activities here are concentrated on social investments, co-operation with nongovernmental institutions and local parties, employees voluntary, company's involvement in philanthropy activities, creating new vacancies, including such for handicapped people. Third sphere of company's activities involves co-operators in selling and buying transactions. The co-operation is based on partnership and rules of honesty, transparency, full communication. Sample activities: keeping delivery and payment deadlines, monitoring the products quality, efficient reactions on clients complaints and these of other co-operations of selling and buying process, considering social and ecological aspects in decision making process (6). The common part of internal and external corporate social responsibility is following the legal rules but at most human rights – social humanism (8).

In the process of corporate social responsibility development various initiatives were raised in order to work out the key rules, directions and standards. (9). Within a few last years the following thesis appeared (8):

- process standards – describe the procedures of creating relations with other parties, communication, building the management systems (AA1000, GRI),
- performance standards – describe what is or is not acceptable (*Global Compact*),
- foundation standards – describe the best practice in particular spheres (OECD directives),
- certification standards – describe the management process in particular area (ISO 26000, SA8000, ISO14001, EMAS),
- screening standards – describe what conditions a company must fulfill to become qualify to a particular group of companies (FTSE4GOOD, DJSGI).

The above standards are not obligatory. The companies decide themselves which standard to follow and which activities to apply. It is customary that the effects are reported and particular reports (which are in most cases the summary of annual activities of the company) are available to public.

2. Social reporting

Thanks to the popularity of corporate social responsibility many international companies publish social responsibility reports. To the most important international action as far as social reporting is concerned is SA 8000 norm and *Global Reporting Initiative*. Corporate social responsibility themes have become an integral part of strategic management and everyday activities of global corporations.

In the reports the companies include: corporate responsibility framework, activities and experience of an employment process, the changes in the company's structure and organisational procedures, communication system , employees' involvement, equal rights of employees (no discrimination), social dialog, education and training, work safety, investments beneficiary for community and environment. The expanded forms of reports include also shareholders opinions about the company (questionnaire results, interviews, opinion polls) and rates presenting the effects of company operations in particular areas of social responsibility.

The report presents in a comprehensive way the company strategy and the results in the area of social responsibility in view of key shareholders groups. Companies in the reports take into account economical aspects, social and ecological activities. The reports available on companies' websites consist of few dozen pages (30-60 pages and more). The report is aimed at: local community and its representatives, customers, contractors, tradesmen, other companies, financial institutions, reporters, students etc. (10). Due to such a big group of recipients the report should be: transparent, comparable, up-to-date, complex, objective, precise and understandable (11).

In Poland since 2007, the competition for the best report of business social responsibility has been organised. In 2009 the winner of the competition was BRE Bank S.A. "Examination in the crisis. Stable development in difficult times". Distinctions were given to GK PGNiG, Lotos S.A. and PKN Orlen S.A. According to the Internet voting the best report was presented by PKN Orlen S.A. Adjusting the competition took place during Responsible Business Forum 2009 conference in 24 November 2009. In the prize-winning report of BRE Bank S.A. institution "Examination in the crisis. Stable development in difficult times. Report on business responsibility by BRE Bank S.A." the most appreciated was the balance in reporting during difficult for financial sector times, including openness of communication and applied verification. There were three other reports worth special appreciation which in fact received special distinctions. The Report of Lotos S.A. Group "Social responsibility report 2008", where maintaining high reporting level and innovative form of presentation were appreciated. Creating an overall report including complicated structure and complexity of Capital Group and presentation of CSR strategic plans gained the report of PGNiG Group "Responsible energy".

In 2009 Report "Responsible business in Poland 2009 was also presented "Good practice". It is a summary of activities that are taken up by firms, institutions and non-governmental organizations in the sphere of business social responsibility and stable development. The report acts as a compendium of knowledge about what happened in 2009 in Poland as far as responsible business in concerned. The publications described good business practice, inspiring examples of responsibility rules appliance in all spheres of business function – in a working place, towards market, society and environment:

Business vs. working place

Examinations concerning the perception of the social responsibility are showing that whether the company is perceived as responsible depends mostly on its employees opinion about it. Trust without which business couldn't function has its source inside the company. Feeling of security, good working conditions, clear communication, possibility of participation – these are the elements which are more and more popular in companies' strategies, in great deal because of CSR development. Good practice, presented in the Report in the sphere of working place, shows inspiring examples of responsible approach toward employees.

Great part of good practice focused on the issues connected with health and security. METRO Group and Nutricia Polska Sp. Z o.o. ran educational activities concentrated on health prevention among their employees. Kampania Piwowarska SA taught its employees its policy of responsible alcohol consumption. Whereas Servier Polska and Wincanton started educational campaign on leukemia and involved their employees into actions of blood and bone marrow donation for these who were in need, moreover Polkomtel SA enabled its employees to gain professional rescue skills. The other but rather new among Polish companies was allowing employees to participate in the process of a company's management. Implementing grassroots initiatives and solutions was the aim of the Media Monitoring Institute initiatives and of PGE Polish Energy Group. However Lotos Group, as a part of internal communication, let its employees to participate in special informative meetings which gave the chance of learning the firm's policy during the time of crisis.

Last year very popular was the practice connected with business ethics. HSBC Bank of Poland launched a code of ethics, Kogeneracja SA settled a special Council of Ethics whereas Profes company prepared the rules of ethical co-operation in working teams.

The great majority of rules concerned the programme of employees' voluntary. The employees supported by their companies took part in social campaigns, collected and distributed funds for aid projects realisation, helped local schools and made children's dreams come true. The voluntary programmes were run by such companies as: Aviva, Bank Gospodarstwa Krajowego, BRE Bank SA, British American Tobacco Polska, DB Schenker, GlaxoSmithKline, Grupa TP, ING Bank Śląski S.A., Kompania Piwowarska

SA, Kredyt Bank SA, Microsoft, PKN ORLEN S.A., Provident, Toyota Motor Manufacturing Poland,
TUiR WARTA S.A., UPS Polska (11).

Business vs. market

Because of the world economy's crisis in 2009 the debate concerning responsibility and ethics in companies' activities took place on a large scale. After the wave of criticism mainly directed into financial sector a very strong belief remained that firm's activities on the market should be crystal and responsible and the examples of good practise. The examples of good practise described in this chapter show that the companies that address this sphere in CSR strategy may be a step forward - being responsible for market parties is not only the source of legitimization but also a place for innovative products and services development.

A very interesting topic that occurred last year in the sphere of "market" was responsible management of supplies chain. ABB Sp. Z o.o. created an infoline for its business partners, DB Schenker took care of its suppliers at the time of flu pandemic, whereas Danone Sp. Z o.o. improved the internet system for milk suppliers. PKN ORLEN SA started to serve coffee at its branches that was produced in fair trade system.

The companies willingly implemented various types of stable development innovations. Axel Springer Polska worked out the system that optimises the production, sale and distribution of press. Kampania Piwowarska SA activated comprehensive management system and reporting results of stable development, however Nestlé Polska due to new technological solutions lowered the weight of the products packaging. As many as 5 firms started actions connected with educating the market. PricewaterhouseCoopers in co-operation with the Academy of Leon Koźmiński settled postgraduate studies "CSR. The strategy of responsible business". The Employers' Council of Polish Distilling Industry trained suppliers as well as people who serve alcoholic drinks in the subject of responsible alcohol sale. The original form of educating the market about CRS was offered by Provident, they announced a competition for journalists who write about voluntary. The Conference of Financial Companies published a guide of ethical vindication, whereas Ergo Hestia Group prepared a series of publications about risk management in running business i.e. environmental risk. The innovative actions were taken by the companies that decided to launch new products and services meeting disabled people needs. TP Group creates

special software that enables disabled people to run the internet browser by the eyes movement, Irving attached signs written in Breill's alphabet on its teas packaging whereas Nordea Bank Polska implemented new service for blind and amblyopic people who want to use bank services.
New category this year has been responsible investing. TFI SKOK SA launched first ethical fund fully using SRI criteria. Such companies as Deloitte Polska, "Forbes" magazine, Kulczyk investments and stock market in Warsaw initiated publication of the first ethical stock index in Poland – Respect Index.

Euro Bank SA started to promote business – as a part of "Win euro bank" young investors had an opportunity to run a bank's branch on franchising terms. Whereas due to PricewaterhouseCoopers and PGNiG SA activities a broad branch initiative in the energy sector was created. During the "Responsible energy" conference representatives of the biggest firms in sector signed the declaration of implementing stable development rules (11).

Business vs. society

The elements that determine function of the economy – business, society, environment – are connected with each other in a systemic way. Changes in one sphere determine changes in others. This, one could say, minor correlation for years has been omitted in companies' strategies. Due to the CSR concept the way how the role of business in society is perceived has changed and what's connected the way how companies face social problems. Examples of good practise presented in this chapter show this important change. The most initiatives in this sphere were connected with companies' social commitment – Alcatel-Lucent employees committed into supporting local society, Kraft Foods Polska SA and Danone Sp. Z o.o. ran campaigns against famine and malnutrition, however it should be highlighted how Danone used social media to succeed in this action. Particularly popular were the programmes which helped children and teenagers ran by ATLAS Group, Muszkieterowie Group, Procter & Gamble and SziK company. Companies supported also elderly people – programmes for them were ran by UPC Polska and Ericsson in Poland. Whereas Infact company offered to nongovernment organisations software for electronic invoices preparing. In favour of nongovernment organisation PricewaterhouseCoopers initiated the alliance "Charity SMS without VAT" (11).

Many practices concerned health and security. Educational programmes were ran by CenterNet SA, PAMSO SA, RoboNET Sp. Z o.o., Telefonia DIALOG SA, UPC Polska and PGNiNG SA. Such companies as Avon Cosmetics Polska and GlaxoSmithKline ran educational programmes connected with social campaigns – first company focused on women harassment while second focused on cancer prevention. Allianz Polska Group promoted transplantology and Amway Polska educated about danger of children choking.

Original initiative was settled by the Capital group of Polish Pharmaceutical Group SA which enabled people who were in difficult financial conditions receiving essential medicine. Whereas Żywiec Group ran few campaigns promoting responsible alcohol consumption. TP Group supported children with hearing defect. Important issue was education concentrated on children security in the Internet – such activities were run by Microsoft and UPC Polska. Górnośląska Spółka Gazownictwa in co-operation with Vattenfall educated about safe usage of gas and energy. Similarly, Polish Society of Industry and Electric Energy Distribution ran educational activities aimed into teenagers about safe usage of electric tools. Renault Polska focused on road safety. While Mazovian Gas Partnership supported education of gas technicians. Moreover companies initiated or continued activities promoting equal rights and diversity by supporting education of children and teenagers (BGś Bank, Bank Gospodarstwa Krajowego, L'Oréal Polska) or disabled sportsmen (Aviva). METRO Group launched scholarship programme connected with education on trade majors whereas Citi Handlowy ran last year financial educational programmes for teenagers and teachers. Gaspol SA focused on local development – with the help of programmes that commit local societies it promotes ecological solutions. ArcelorMittal Poland also took care of local shareholders by creating a special internet service NHpedia which describes the history of Nowa Huta (11).

Business vs. environment

Environment is a company's shareholder that can't state its opinion by itself. It needs representatives that represent its business – nongovernment organisations, administration, consumers, political leaders. While development of ecological consciousness environment protection becomes an integral, motivated element of a business strategy, moreover many initiatives goes further than legislation rules into sphere of innovations.

The popular practice of 2009 was launching the ecological solutions in a working and production place. "Ekobiuro" projects were ran by ProLogis, Henkel Polska and Allianz Polska Group. Ecological modifications of internal systems included also IT innovations – TP Group launched such solutions as "green IT". ABB Sp. Z o.o. ran its factories in Łódź region through eco-effectiveness requirements.

Many companies ran educational activities focused on enlarging their shareholders' consciousness about ecology. Such initiatives were undertaken by UPC Polska, Tesco Polska, Bayer Sp. Z o.o. and KGHM Ecoren. Ikea Retail created a website educating its clients about domestic ecological solutions. On greater scale, environment protection activities concerned such projects as biodiversity (LOTOS Group), pollution removing in local environment (British American Tobacco Polska), measuring and neutralizing or limiting of greenhouse gas emission (Bank Ochrony Środowiska SA, VELUX Group in Poland), consumers' education and involvement (Żywiec Zdrój SA) and management of waste (Total Recycling Services, Coca-Cola HBC Polska and Coca Cola Poland Services). Last year PKN Orlen SA continued the activities as a result of joining international chemical branch initiative – Responsible Care. While UPS Polska in co-operation with Polish Agency of Air Navigation started a project aimed at launching ecological methods into aeroplanes navigation (11).

Management and reporting

In discussions about business responsibility now and then we hear same question: "Responsibility - for what?". While majority of us on the basis of intuition or knowledge and experience is able to answer this question, in the sphere of management we require concretes and facts. The reporting and CSR management systems enable precise verification, due to concrete measures, of degree of social firm's responsibility realisation. Nowadays in Poland reports and CSR management systems are measures of rare usage by firms and their shareholders (11).

3. Case study – ArcelorMittal

In 2008 ArcelorMittal group published the first report on corporate responsibility for the year 2007. Its title „Taking responsibility for transforming tomorrow" related to the marketing motto of the corporation „transforming tomorrow". The report is based on three core values: corporate sustainability, quality and leadership. The corporate activities were addressed at: customers, shareholders, employees and communities.

The report presented corporate activities in four areas of social corporate responsibility: governance, workplace, natural environment, development of local communities. The report consisted of 70 pages and was distributed in 11 thousand copies. The report was also available on the company website. As opposed to previous publications (Social Review) by applying a lot of strategic measures the report is more accurate and clearer. The report was the first summary of social dialog between internal and external stakeholders (12).

The aim of leadership in ArcelorMittal capital group is to transform steel industry and local communities according to values of well-balanced development and corporate responsibility. The company set up twelve teams collecting information on the entire corporation which contribute to building the corporate level strategy as a whole and prepare them to be implemented into the social responsibility system according to ISO 26000 standards. The areas of responsibility of each team are presented in table 1.

Table 1.

Main areas of activity of ArcelorMittal capital group teams

Areas of activity	Areas of teams' responsibility
Governance	o board independence, o equal rights among shareholders, o dialog among shareholders.
Workplace	o health and safety, o social dialog, o training and career development, o world working standards, o labour commitments.
Environment	o *"Greenhouse",* limitation of greenhouse gas emissions to the environment (in particular carbon dioxide) o waste minimalization, water recycling and pollution prevention o research and development (R+D).
Społeczności	o care of developing local community, o social and ecological investments, o human rights and social engagement.

Source: based on social corporate report 2008 (www.arcelormittal.com).

Corporate responsibility guarantees the highest standards, for example in equal treatment of all shareholders, board independence, precisely defined roles and responsibilities of directors and management workers. The ethical management in ArcelorMittal takes place at all levels of management. The scope of activities in corporate responsibility management area in ArcelorMittal is presented in table 2.

Table 2.

Corporate responsibility management in ArcelorMittal

Group in organizational structure	Areas of activities
CR Orientation Committee	o activities in relation to social responsibility, setting operational and strategic direction, introduction of principles and rules, monitoring and performance review.
CR Group Committee	o implementation of CR Orientation Committee dirctives, o comprising representatives for health, safet, security, environment and energy, o maintaining social dialog of risk management and ArcelorMittal foundation.
CR Corporate Team (CR Corporate Team)	o communication with employees and shareholders (indicating specific areas of action, such as: reduction of gas emission, improving safety), o improving corporate social dialog, o ensuring working standards, o developing teamwork, o improving the level of employee engagement.

Source: based on social corporate report 2008 (www.arcelormittal.com).

Social responsibility management is currently directed by a Board of Directors represented by eight nationalities and is at the same time responsible for corporate strategy. Board members were workers and trade union members in the past. This allows perceiving corporation problems at all levels. The Board delegates day-to-day management of the company to a Group Management Board. A very important aspect in corporate management is clarity and quality in communication with shareholders. The most important aims of corporate responsibility are listed in table 3.

Table 3.
The most important aims of corporate responsibility in ArcelorMittal.

Areas	Aims of activity
Workplace	o increment of work safety (incidents reduction), o legal exceeding of set trade unions by dialog with labor groups, o improvement of training qualities among employees.
Environment	o intensive reduction of carbon and energy consumption in steel production, o reduction of water usage and dust emissions, NOx i SOx in steel production, o complete implementation of Environmental Management System according to ISO 14001, o increment of steel usage in innovative products, o safe and renewable technologies.
Communities	o connection with society through economic development, o improvement of effectiveness of social investments, o implementation of the highest standards in the area of human rights.
Management	o maintaining high standards of corporate governance and dialog with shareholders/stakeholders..
Business ethics	o implementation of ethical code into practice among employees groups, o rising ethical awareness of eomployees.
Supply chain	o reduction of negative impact on natural environment, o raising awareness of fundamental values accepted by a company in a supply chain, o increasing social development beyond immediate operation of the corporation.

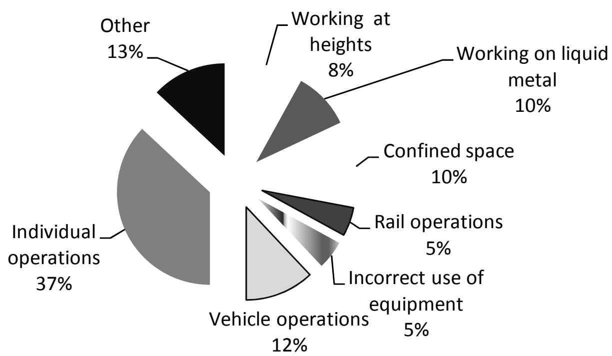
Source: based on social corporate report 2008 (www.arcelormittal.com).

Implementation of corporate governance concept in ArcelorMittal group requires cooperation:

- with employees (taking into account employees interests),
- with trade unions and their offices (negotiating collective agreements about work),
- with main suppliers and receivers (realization of "One face" politics – standardization of operations in the whole corporate structure),
- with main competitors (collaboration strategies, cooperation),
- with government, regulatory agencies, administration offices of supervision and control (labour inspections, environmental sanitation services, building),

- with organizations and societies that have influence on state regulations and public opinion.

Arcelor Mittal group operates in industrial sector of high occupational hazards thus implemented and realizes a strategy of "*zero injuries*". The strategy is based on effective leadership, cooperation and dialog among all employees, opinion exchange, training on occupational development and programs to built awareness of work safety and hygiene. Global Health and Safety Committee is the managing organ and it is made up of representatives from each of the business areas. In 2007 the amount of US$ 216.4 million was spent on work safety measures, which represents 4% of the total amount of yearly expenditure. Pic. 1 presents proportional breakdown of injuries in steel operations in the company. The corporation implements *programme to build employee awareness of work safety and health*. The programme is based on a real cooperation among employees who not only support each other but also control own behaviors, as a result of which self-improvement process is realized. The employees release the feeling of responsibility for own and others safety. There is an atmosphere of mutual trust and openness in the company. This situation is conducive to effective internal communication. Through communication the whole process of changes in employees attitude and motives of action is achieved. Personnel that receives information on work safety can improve skills in selecting right and wrong activities.



Pic. 1.: The incident structure in steel operations in ArcelorMittal
Source: Social report ArcelorMittal 2008.

Each department of ArcelorMittal implements a programme to upgrade work conditions. This programme is prepared for a particular calendar year and consists of planning tasks which realization should contribute to the improvement of work conditions.

Health and safety days are organized in the whole corporation. Programmes to reduce the negative impact of noise, dust emission and other factors on employees health are realized, actions to stop cigarette smoking, alcohol use and campaigns on HIV and AIDS are encompassed. In June 2008 ArcelorMittal signed an agreement with union trades related to occupational health and safety.

The highest standards of occupational health and safety were implemented in all companies of the group. In organizational structures Health and Safety Corporate Office was created. Until the year 2011 all corporation plants should obtain OHSAS 18001 certificate. So called medical plan of action directed at employees' health and safety (prophylactic examinations, symposium on health protection) was prepared (13).

Changes taking place in the companies' environment led to the evolution of ideas on the main factors of market success. To the traditional sources of competitive advantage belong: products, technological processes, and financial resources. Whereas modern understanding of market success is based on human resources, which means on employees of high occupational qualifications, creative employees, flexible, mobile and entrepreneurial. ArcelorMittal corporation as a modern organization chose occupational development of employees. There are organized trainings in the group's plants, functioning Mittal University and Manager Academy. As a result of project global reach training programmes are also available in English (e-learning). At Global English website (www.globalenglish.com) the employees have a possibility to learn English online 24 hours per day, 7 days per week for 60 users in Poland. Whereas Online Training Centre (OTR) Thomson NETg (www.netglearning.com) is a database with hundreds of trainings in functional areas such as accounting and finance, customer service, human resources management, sales, marketing, project management or planning to which currently 63 users in Poland have access. Implementation of further initiatives in framework of Mittal University such as Business Book Reviews (www.businessbookreview.com) and Steel University (www.steeluniversity.com) (14)[16] is planned. Manager Academy offers training, courses for managerial Staff. The structure of Manager

Academy programme consists of three fundamental blocks:

- block 1 *Attitude and knowledge* – its aim is to build new occupational attitudes, new organizational culture and company value,
- block 2 *Management Skills* – covers four topics: performance management, leadership, personal effectiveness, leadership in a team; the aim of the programme is to upgrade managerial skills of the management Staff.
- block 3 *Professional Skills* – training on art of presentation, innovative and analytical thinking, stress control, decision making and problem solution, labor law, job interview, production cost management, lean manufacturing, value chain management, project management, sales negotiations, sales process management, techniques of telephone sales manners, motivating and delegating of powers, solving conflicts and difficult situations in the company, business communication, building team cooperation, employee performance review and shift management (15).

Manager Academy programme is consecutively updated with new training topics. It is a long-term programme (its further editions are planned). Direct spending on education and development in the year 2007 was US$ 112 million.
The company focuses on development of leadership competencies. A new organizational corporate scheme was created which concentrates on:

- using management competencies
- result orientated decision making
- strategic thinking
- teamwork
- effective communication
- increasing competency (learning and occupational development)
- stakeholder and market orientation.

In the report published by the corporation the role of company in environmental protection is highlighted. The significant problem is to reduce the emission of CO_2. The company uses two ways to reduce CO_2 emission:

- direct reduction of CO_2 emission in production processes,
- steel recycling (globally recycled steel brings 600 million tones of CO_2 savings annually). ArcelorMittal is the biggest recycling company in the world.

The company rationally manages resources and waste. On average the annual consumption of water for steel production is about 18 million m^3 of water. ArcelorMittal used up in production processes 2.2 billion m^3 of water in the year 2006. The aim of corporation is to reduce water use, especially in North America. Sewage disposal takes place strictly through the system of settling tanks and separators. Only rain water is drained into surface water or ground water. In the 2007 untreated wastewater accounted for less than 1% of all sewages, in 2008 all sewages undergone treatment.

In waste management about 83% of waste from production processes is subject to recycling. The rest is neutralized or temporarily stored (16).
In the year 2007 ArcelorMittal corporation assigned US$ 215 towards R+D (Research and Development), including modern solutions in environmental protection. It is worth paying attention to the fact that 79% of all operations received ISO 41001 certification. The first comprehensive review of the environmental impact was carried out and the map of activities prepared. In May 2008 energy politics were implemented and US$ 500 million transferred towards energy efficiency improvement programme for the years 2008-2012. To reduce pollution emission to air US$ 306 million was spent.

Environmental protection requires product improvement. ArcerolMittal employs over 1400 researchers in 14 research centers located in Europe, Canada and Brazil. US$ 210 million was invested in new product development in 2007.

ArcerolMittal contributes to shaping the world's economy not only through financial contributions but also by creating new products and communities development. Realization of the marketing motto "*transforming tomorrow*" means engagement into social-economical development. In countries all over the world, ArcelorMittal builds objects for local communities (roads, hospitals, outpatient clinics, schools etc.). It also transfers financial resources for a purchase of necessary equipment for non profit institutions. Community development is included in:

- health care (prophylactic examinations)
- infrastructure development (buildings, equipment)
- education (building schools, purchasing educational equipment).

Community care also shows in creation of new workplaces. In Liberia the corporation invested US$ 1.5 billion into steel and mining together with railway and port development ensuring 3.5 thousands of new jobs.

The next component of corporation strategy is local communities' skills development through financing training and courses. Social development strategy is based on:

- sustainability – enables development of communities in the long term.
- locality – takes into account cultural nature of local communities (traditions, customs, habits)
- integrity – cooperation of communities representatives including local authorities, non-governmental organizations and private partners.

In the process of strategy realization the corporation created Responsible Business Committee which assignment was to focus on particularly urgent social matters.

To sum up, the responsible business programs in ArcelorMittal have been carried out for three years (since the year 2007). The first corporation report presenting the scope of realized tasks was published in 2008. In the year 2009 local and regional reports of each company being a part of ArcelorMittal group e.g. ArcelorMittal Ostrava (the report available at www.arcelormittal/ostrawa) were published.

4. Summary

In the last few years huge changes have taken place in the perception of business and its role in present economy. Corporate social responsibility is a conception according to which companies voluntarily participate in creating better society and cleaner environment. The advantages for the companies that publish social reports are as follow (10)

- strengthen of the company's image as a social responsible company,
- building a new reputation as a social responsibility corporation,

- creating new business opportunities (new markets, innovations in production, better technological solutions etc.),
- assurance of stabilization and understanding within the surrounding (within different shareholders),
- increase of the corporation's attractiveness as an employer (social responsible business gathers high qualified work force),
- increase of noneconomic motivation (raise of employees' motivation in every day work),
- increase of work effectiveness by improving and rationalizing the processes,
- building the synergy effect inside the company as well as outside by intensive communication within the company and various social groups.

Corporate social responsibility leads to development of new partnership relations inside as well as outside the company. A new form of social dialog and new company value is created which is based on economical, social and ecological unity.

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Chapter 2.3.

KLASTER – POTENCIÁL ZVYŠOVANIA VÝKONNOSTI ORGANIZÁCIE

CLUSTER – THE POTENTIAL FOR INCREASING ORGANIZATION'S PERFORMANCE

Jolanta STASZEWSKA[1]

Kľúčové slová: klaster, podnik, efektívnosť

Abstrakt
Hlavný cieľ klastra, využívajúci pozitíva moderných sietí, integruje v sebe čiastkové ciele jeho účastníkov. Úroveň dosiahnutia stanovených cieľov spätne ovplyvňuje štruktúru klastra a jeho rozvoj. Následne možno hovoriť o efektívnosti klastra - je to synergický efekt, vyplývajúci zo spoločne popísaných, ale rozdielne realizovaných trhových cieľov účastníkov, vplývajúci na trhový úspech každého podniku zvlášť, ale aj siete ako celku. Posudzovanie efektívnosti klastra je potrebné realizovať na základe úspechu jednotlivých podnikov, ktoré sú súčasťou klastra, a ktorí svojou kooperáciou vytvárajú pre klienta novú hodnotu. Miera jej akceptácie trhom je ďalšou úlohou, ktorá by si vyžadovala posúdenie pri úvahách o efektivite klastra.

[1] Doc. Ing. Jolanta Staszewska, Phd
Politechnika Śląska v Gliwiciach,
Fakulta materiálového inžinierstva a metalurgie,
Katedra riadenia a informatiky.

1. Úspech klastra

Závery v tejto časti sú realizované na základe 41 výskumom o klastroch v Poľsku, ktoré uskutočnila a ďalej uskutočňuje autorka. Dôsledky klasteringu autorka na základe získaných poznatkov rozdelila do troch úrovní, t.j. mikro, mezzo a makro, čo približuje tab. 1

Analyzujúc prípady poľských klastrov možno predstaviť výsledky klastrovania v dvoch variantoch.

Prvý variant sa týka klastrov, ktoré fungujú už niekoľko rokov, majú určitú organizačno-právnu formu a patria do skupiny najpokročilejších v svojom životnom cykle.

Druhý variant sa týka klastrov, ktoré sú na začiatku svojej cesty, v spúšťacej fáze, zodpovedajúcej tzv. projektovaným klastrom. Pokus urobiť takéto rozdelenie sa zdá byť správny vzhľadom na potrebu vnímania istého špecifika efektov poľského klasteringu a jeho vplyvu na podnik.

Okrem toho si pozornosť zaslúži fakt, že v poľských podmienkach je ešte ťažké rozoberať efekty klasteringu na makro úrovni. Vzhľadom na počiatky tohto procesu sú výsledky na národnej úrovni zatiaľ nepozorovateľné. V prípade činností jednotlivých klastrov je zjavné priťahovanie zahraničného kapitálu a nárast exportu, ale opäť, vzhľadom na národné hospodárstvo sú to činnosti relatívne malého rozsahu.

Na regionálnej úrovni sú už citeľné vplyvy činnosti klastrov. Týka sa to ale najviac rozvinutých klastrov. Efekty sa týkajú znižovania nezamestnanosti a inicializovania novej politiky vzdelávania personálu. Tá spočíva v tom, že broker klastra koordinuje vzdelávanie mládeže už na úrovni stredných škôl takým spôsobom, ktorý zabezpečuje personálne potreby podnikateľov v klastri – počtom aj kvalitou (napr. klaster Dolina Lotnicza). Okrem toho, spolupráca v klastri vyžaduje od podnikateľov využívanie moderných informačných technológií, čo priaznivo podporuje šírenie moderných komunikačných techník v regióne.

Tab. 1.

Efekty činnosti klastrov v Poľsku

	Úroveň mikro	Úroveň mezzo	Úroveň makro
Aktívne klastre	o zvýšenie obratov, zisku, o zmodernizovanie metód riadenia ľudských zdrojov, o stimulovanie podnikania, o ľahší prístup k zdrojom, o zníženie transakčných nákladov, o výroba produktov vyššej kvality, o zlepšenie vyjednávacej pozície, o všetky efekty z tejto úrovne vyskytujúce sa v projektových klastroch,	o zníženie nezamestnanosti, o iniciovanie novej politiky vzdelávania personálu, o rozšírenie informačných technológií kvôli cieľom oblasti komunikácií, o zvýšenie úrovne identifikácie s regiónom,	o pritiahnutie zahraničného kapitálu, o zvýšenie exportu,
Projektované klastre	o prelamovanie mentálnych bariér podnikateľov, o zabezpečenie dlhotrvajúceho úspechu malým podnikateľom, o tvorba nových formálnych úrovní komunikácie, o zdokonalenie neformálnej komunikácie stmeľujúcej spoluprácu, o tok skrytých poznatkov, o možnosti zavedenia capital venture (rizikového kapitálu), o objavuje sa obava pred zbyrokratizovaním kontaktov s lídrom a okolím a obava zo znášania nákladov spojených so vstupom do klastra,	o vplyv na obraz regiónu,	chýba

Zdroj: vlastný elaborát.

Pokročilejší klaster priťahuje investorov, posilňuje región investíciami, stimuluje podnikateľské správanie. Podnikateľské vnímanie merateľných efektov prostredníctvom činností v klastri (zvýšenie obratov, zisku, rentabilnosti) zvyšuje ich náklonnosť k inováciám. Zvýšenie mieri inovácie jednotlivých subjektov klastra v poľských podmienkach zatiaľ ťažko možno spojiť s inováciou regiónu. Preto možno hovoriť o inovácií ako o dôsledku klastrovania predovšetkým na mikro úrovni, čiže v podniku.

Podnikatelia participujúci v klastri dosahujú efekty spočívajúce predovšetkým vo zvýšení obratov, zisku, znížení transakčných nákladov, jednoduchšom prístupe k zdrojom. Stávajú sa konkurencieschopnejší v porovnaní s podnikmi, ktoré nie sú spojené s klastrom, kvôli nižšej cene produktu. Majú zjednodušený prístup do výskumno-rozvojovej sféry, čo zvyšuje možnosť vyrábať inovované produkty a produkty s vyššou kvalitou.

Podnikatelia, ktorí spoluprácou spájajú svoje sily, majú ako klaster zjednodušené možnosti vstupovať na nové trhy. V porovnaní s inými podnikmi sa zlepšuje ich vyjednávacia pozícia a uchádzanie sa o prostriedky pomoci je jednoduchšie vďaka činnosti sieťového brokera. Často sú zavádzané nové princípy personálnej politiky. Upúšťa sa od všeobecne prijatého modelu riadenia ľudských zdrojov, zvaného sito, a prechádza sa na model budovania ľudského kapitálu.

Predostreté efekty sa však týkajú podnikov aktívnych v starších klastroch (z prvého variantu). Naopak, v prípade vznikajúcich klastrov, tzv. projektovaných, sa viditeľné efekty klastrovania týkajú výlučne mikro úrovne a majú kvalitatívny charakter.

Vo fáze vzniku nemožno ešte hovoriť o ekonomických výsledkoch podnikov, lebo na ich získanie sa podnikatelia ešte len pripravujú. Viditeľné efekty sa týkajú:

- prelamovania mentálnych bariér vyskytujúcich sa medzi manažérmi, ktoré znemožňujú spoluprácu; pomaly sa vytráca pocit nebezpečenstva týkajúceho sa obáv z krádeže nápadov, kupovania partnerov,

- buduje sa vedomie zabezpečenia dlhodobého obchodu pre malé podniky,
- aktivizuje sa podnikateľská klíma,
- zdokonaľuje sa komunikácia pomocou vytvárania jej formálnych, nových úrovní,
- dochádza k zdokonaleniu neformálnej komunikácie, podnikatelia sa častejšie kontaktujú v atmosfére nezáväzných priateľsko-obchodných stretnutí, čo posilňuje väzby v klastri,
- prejavuje sa slobodný tok tzv. ukrytých poznatkov,
- tvoriace sa kontakty medzi podnikateľmi, v rámci školiaco-informačných programov propagujúcich klastering, môžu priniesť ovocie vo forme neveľkých vstupných investícií venture capital.

Na základe vyššie uvedeného je zrejmé, že výsledky klastrovania v Poľsku majú výlučne pozitívny charakter. Táto situácie neznamená, že klaster prináša len výhody. Negatívnymi dôsledkami môžu byť: odcudzenie sa skupiny podnikov okoliu a nadmerné uzavretie sa siete, vytvorenie vnútorných dohôd – zodpovedajúcich kartelom, zánik prirodzenej tendencie konkurovať. Takéto vedľajšie dôsledky boli popísané medzi podnikmi dobre rozvinutých svetových klastrov. V Poľsku k takej situácii ešte nedošlo, preto sa dôsledky obmedzujú iba na výhody.

Pre klaste je dôležité rozpracovať metodiku, ktorá umožní hodnotiť ich úspech. K riešeniu tohto problému, autorka navrhuje pristupovať na základe modifikácii strategickej analýzy týkajúcej sa činiteľov úspechu sektora. Pri adaptovaní na klaster, možno navrhnúť nasledovné hodnotenie kľúčových činiteľov úspechu klastra.

Tab. 2.
Hodnotenie kľúčových činiteľov úspechu klastra (príklad výskumu pre klaster X)

LP. č.	Činitele úspechu	V - váha (1 - 3)	H -hodnotenie (1 - 5)	Vážená hodnota V x H
1	Zhustenie podnikov daného odvetvia v regióne	2	4	8
2	Ponuka pochádzajúca z potenciálne konkurenčných podnikov	2	3	6
3	Prepojenie účastníkov klastra s regiónom	3	5	15
4	Účasť jednotiek územnej samosprávy v klastri	3	5	15
5	Reprezentácia „zakladateľov" klastra v hospodárskom spoločenstve	2	4	8
6	Lokalizácia klastra v regióne so silnou tradíciou	3	5	15
7	Úloha klastra pre odvetvia kraja	3	4	12
8	Úroveň pokrytia interpersonálnymi vzťahmi regiónu (mestá v klastri)	3	3	9
9	Lokálna značka	3	4	12
10	Program rozvoja odvetvia v priestore činnosti klastra	2	4	8
11	Získavanie finančných prostriedkov z EÚ na rozvoj klasteringu	3	4	12
12	Možnosť získavať z daného odvetvia rôznorodé produkty	2	3	6
13	Formalizácia členských procedúr v klastri	2	4	8
14	Vplyv samosprávy zvyšujúci pocit stability medzi účastníkmi klastra	2	4	8
15	Stimulácia klastra rôznorodými externými projektmi	3	4	12
16	Zvyšujúci sa dopyt po rôznych druhoch ponuky z daného odvetvia	2	4	8
17	Zhodnosť smerov rozvoja domáceho produktu daného odvetvia s určenými programami rozvoja tohto odvetvia v klastri	1	3	3

Tab. 2. (pokračovanie)
Hodnotenie kľúčových činiteľov úspechu klastra (príklad výskumu pre klaster X)

LP. č.	Činitele úspechu	V - váha (1 - 3)	H - hodnotenie (1 - 5)	Vážená hodnota V x H
18	Podpora domáceho podnikania verejnými orgánmi	1	3	3
19	Sprístupňovanie pracovného trhu v odvetví pre zahraničný personál	1	2	2
20	Rozširovanie sa životného štýlu, ktorý vytvára potrebu nových produktov v odvetví, ktoré môže ponúknuť aj klaster	1	3	3
21	Záujem o prácu v odvetví medzi mládežou v kraji	1	3	3
22	Úroveň ponuky v profesiách spojených s daným odvetvím	1	3	3
23	Použitie moderných technológií na odosielanie informácií	2	4	8
24	Veľkosť trhu odvetvia a predpokladaný rozvoj	2	5	10
25	Sezónnosť alebo stálosť ponuky	1	4	4
26	Intenzita konkurencie na trhu klastra	3	3	9
27	Vysoké kapitálové požiadavky v odvetví	2	3	6
28	Úloha spoločenských, politických ukazovateľov, ukazovateľov prostredia atď. pri rozširovaní klastra	2	4	8
29	Investičná atraktivita prostredia	3	4	12
30	Inovačný potenciál v odvetví	2	2	4
31	Úroveň trhových poznatkov podnikov v klastri	3	3	9
32	Úroveň vplyvu rôznych projektov na klaster	2	4	8
33	Prítomnosť lídra v klastri	1	3	3
34	Úroveň prepojenia klastra s vedou	2	2	4

Tab. 2. (pokračovanie)
Hodnotenie kľúčových činiteľov úspechu klastra (príklad výskumu pre klaster X)

LP. č.	Činitele úspechu	V - váha (1 - 3)	H - hodnotenie (1 - 5)	Vážená hodnota V x H
35	Úroveň internacionalizácie v majetkových a organizačných kategóriách	1	2	2
36	Kritické ohlasy na klaster	2	3	6
37	Fáza rozvoja klastra	3	1	3
38	Zdroj klastrových iniciatív	2	1	2
39	Úroveň unikátnosti produktov regiónu	1	2	2
40	Propagácia poznatkov o klastri	2	2	4
41	Mechanizmy výmeny informácií medzi klastrom a okolím	2	2	4
42	Vplyv miestnych orgánov na odvetvie	1	2	2
43	Úroveň zdanenia podnikov	1	1	1
44	Trendy v odvetví	1	1	1
45	Úroveň konkurencie zahraničných ponúk	1	3	3
	Súčet hodnotenia			**294**

Zdroj: vlastný elaborát.

Získaný celkový súčet 294 bodov bol pridelený príslušným činiteľom úspechu klastra, pri predpokladanom maximálnom počte 675 bodov.

Znamená to, že na základe ohodnotenia kľúčových činiteľov, je možné určiť úspešnosť klastra:

- 0 - 134 b. – klaster nie je úspešný
- 135 - 269 b. – nízka úroveň dosiahnutia úspešnosti klastra,
- 270 - 404 b. – stredná úroveň dosiahnutia úspešnosti klastra,
- 405 - 539 b. – dobrá úroveň dosiahnutia úspešnosti klastra,
- 540 - 675 b. – veľmi dobrá úroveň dosiahnutia úspešnosti klastra.

Získané celkové hodnotenie pre činitele úspešnosti klastra ho umožňujú umiestniť v triede strednej úrovne dosiahnutia úspešnosti. Znamená to, že skúmaný klaster X má polovičnú príležitosť na to, aby dosiahol úspech pri využití odkrytých stimulačných činiteľov.

Najdôležitejšie prvky vplývajúce na úspešnosť klastra boli určené tak, že sa vybrali tie činitele, ktoré získali najvyššiu váženú hodnotu.
Najdôležitejšie vnútorné činitele stimulujúce klaster k úspechu, v priklade klastra X, sú:

- prepojenie účastníkov klastra s regiónom,
- aktívnosť regionálnych samospráv v klastri,
- výskyt významných tradícií spojených s odvetvím v regióne,
- vlastnenie lokálnej produktovej značky,
- investičná atraktivita odvetvia.

Medzi najdôležitejšie vonkajšie činitele stimulujúce klaster k úspechu zase pre skúmaný klaster patrí:

- získavanie fondov z EÚ,
- stimulovanie klastra rôznorodými projektmi.

Z toho vyplýva, že klaster potrebuje na úspech prísun zdrojov, investícií, podpory samosprávy a využívanie tradície daného odvetvia v regióne, ako aj predaj značkových produktov. Pre úspešnosť klastra sa zdá byť najmenej dôležitou skutočnosť vysokého zdanenia živnosti podnikateľov a to, že má klastrová iniciatíva a jej posilňovanie charakter „z hora".
Priemyselné klastry sú v Poľsku viac pokročilé vo svojom rozvoji ako klastry v oblasti služieb.

V klastroch pozorujeme budovanie novej hodnoty pre klienta a je možné hovoriť o rozvíjaní sa nových zásad riadenia, včítane marketingu.

Riadenie realizované prostredníctvom tradičných funkcií – plánovacej, organizačnej, motivujúcej a kontrolnej získava iné dimenzie. Nie je riadený výlučne jednotlivý podnik, hoci ten proces pokračuje, ale riadená je sieť ako celok, v ktorej sa dá vypozorovať synergický efekt týkajúci sa zdrojov na vstupe a výsledkov na výstupe sústavy.

Ak sa v klastri vyskytne broker, vtedy prostredníctvom brokera sú realizované riadiace funkcie práve v oblasti získavania zdrojov a predaja produktu. Tvorí sa spoločný marketing, ktorý sa vzťahuje na vytváranie spoločného produktu, politiky distribúcie, propagácie či ceny produktu, ktorý vytvoril klaster.

Podniky, ktoré medzi sebou spolupracujú, sa budú rozvíjať ako celok v smere určenom klastrom. Úspech klastra je úspechom podnikov, ktoré sa na ňom zúčastňujú. Klaster neumožňuje, aby sa podniky individuálne zastavovali v rozvoji. Úspech je efektom synergie kooperácie v sieti.

Záver

Klaster sa ukazuje ako atraktívna perspektíva pre podnikateľov, hlavne vzhľadom na predpokladané ekonomické a iné výhody prestížneho charakteru, ktoré očakávajú podnikatelia.

Preskúmané dôsledky v spojitosti so stimulujúcimi a destimulujúcimi faktormi nabádajú k ďalšiemu výskumu v oblasti hodnotenia, či klaster je pre podnikateľov správnou cestou ich rozvoja v aspekte ich aktívnosti na trhu.

Chapter 2.4.

CALCULATION MODEL OF TEACHING COSTS IN A UNIVERSITY

VÝPOČTOVÝ MODEL NÁKLADOV NA VYUČOVACIU HODINU V UNIVERZITNOM PROSTREDÍ

Małgorzata JUCHA**, Grzegorz BOCEWICZ*, Józef MATUSZEK**

Abstract

A calculation model of teaching costs in a university is a system of guidelines, notions and relations to facilitate an assessment of the costs generated by individual university departments, majors, subjects etc. The existing calculation models based on the assessment of costs with the use of precision data prove to be ineffective in practice. The major drawback of these systems is the fact that it is not possible to take into account non-precision data in relation to cost generating factors (e.g. the number of didactic groups, hourly rates etc.). This article presents the author's own proposal of a cost calculation model based on the formalism of fuzzy logics (with the use of the L-R representation). On the basis of the model proposed, it is possible to assess the costs of an academic subject with imprecise information concerning cost generating factors, or the values of those factors are assessed which imply the values set of the cost of a subject.

* Politechnika Koszalińska, ul. Śniadeckich 2, 75-453 Koszalin

** Akademia Techniczno – Humanistyczna, ul. Willowa 2, 43-309 Bielsko-Biała

1. Introduction

Teaching of students in universities is a process of the provision of educational services. Considering their complex structure, it is not always possible to exactly define some of cost components. There are various methods and ways to determine them, however not all of them are of a practical use (6).

The Institute of Problems of Contemporary Civilization in Warsaw (3) was the first to make an attempt to develop a cost calculation model. This is a complex and inaccurate model. The authors of this model divide costs into three groups: the costs of the existence of a university, teaching costs, costs of studying. The model proposed is described with 22 variables and 22 equations. The complexity level of the computational algorithm is not proportional to the accuracy of the results and the data required today for the purpose of the management of a university. The division proposed provides overall information without any possibility to assess the costs of the tasks performed by the organizational units of the university. In practice, models are necessary which facilitate the valuation of costs of e.g. fields of studies, and this one gives no such results.

The model of teaching costs is built on the basis (6) of two assumptions:

- the didactic hour is the carrier of costs,
- the student is the carrier of the costs of activities.

With the aid of the carrier of costs, the average teaching cost of a student is calculated per one didactic hour. With the aid of the carrier of costs, the number of didactic hours per one student is calculated. The product of these two factors presents the average cost of teaching a student.

The results of calculations in this model aim at the determination of the average cost of providing a major or a subject because of one the type of data is an average hourly rate. Such a method to calculate costs leads to approximations which are too large. This model lacks precision as to the rates applied and the carrier of costs, i.e. the student and the hour. This forces the user to possess information concerning the number of didactic hours in a week or a semester. This model does not take into account the budget which is at the disposal of the university. The calculation of the hours in semesters and in weeks is not justified as the structure of didactic hours is determined at the beginning of the semester, and the number of didactic hours for individual subjects is set in teaching standards.

However, in opposition to the models presented in the literature, the model presented in this study does not deal with the issue of indirect and direct costs, because this is a calculation model of the costs of a subject or a field of study that takes into account the type structure of costs. It enables one to calculate those variables from which the cost depends with a specific budget, and also to assess the budget with given variables. The model proposed provides answers to a number of detailed questions:

- How many didactic groups can be formed with a specific budget allocated to a subject?
- What deviations from the accepted cost level are permissible?
- What cost of a subject can be expected with specific data that forms this cost?

The proposed calculation model of teaching costs answers these questions.
In accordance with this model, the number of didactic hours is important, which depends from the number of student groups. The advantage of this model is the possibility to use non-precision data, which on the budgeting stage is determined as "between", "circa", and "not more than".

2. Calculation of teaching costs

2.1. Modeling of teaching costs

In order to implement actions concerning the functioning of a university both in the area of costs and receipts, the managers should be in the possession of an initial calculation, which is prepared quickly and correctly, so that the effects of making a specific decision could be determined.

When preparing to open a new field of study, prior to taking any decision, a university should collect information concerning the following:

- any additional costs to be borne by the university,
- the value to be reached by the costs during the first year,
- the costs that will burden the university's budget in the coming years.

It is impossible to obtain this information with the currently used cost statement, which is based on historic data. This requires a lot of effort and time, which is too a cost value: "time is money".

A solution was proposed based on the results of an analysis of the structure of the expenses by the type conducted on the basis of the report data from several universities (4). The conclusions from this analysis indicated that it is the staff costs that are the most important costs borne by the university as they constitute over 70% of the total costs. If we exactly assess staff costs, the remaining value can be added as a margin of costs.

For the calculation of staff costs, the data concerning those parameters that have an influence of these costs are required. When analyzing staff costs, it was established that the manager of a unit, before taking a decision concerning opening of a new major, is to know those analytical values which have an influence on the calculation of the final cost, i.e. the following:

- the number of lecture groups,
- the number of exercise groups,
- the number of laboratory groups,
- the staff,
- the remuneration rates of those employed for the needs of the major.

Those in charge of the university are to be familiar with the value of the costs; they should also know what receipts they can expect in connection with the subsidy granted as well as fees for studies related to the opening of a specific major. Owing to this information, it can be determined what the results of decisions taken will be. If a loss results from a specific action, it is to be assessed in what period it will be maintained; a profit is the result, and what its value will be.

In order to obtain complete information in this area, the statement of the teaching costs makes it possible to capture the full teaching cost during one financial year. In order to find such an arrangement of costs that will provide an answer to the question: how much does one student cost within a year?, one needs to establish and analyze several factors that are required to make managerial decisions, such as the following:

- what product this will be (e.g. a new major),
- data concerning the demand in the area of dynamics,

- qualitative calculations (fashion, demand on the labor market for specific specialists, easy and comfortable studying),
- the picture of the situation on the market.

One needs to pay attention to the fact that concerning setting of fees for educational services, costs are not the only value which limit their amount. Fees for law, medicine and psychology studies may serve as an example. The prices for the abovementioned majors depend from the demand, while the price of extramural studies is not prohibitive to future students. Technical majors are an example where the price for studies constitutes the main factor to undertake studies: they require from the future student a lot of effort during studies. These studies are much more difficult from the point of view of the subjects and the skills which are verified on technical studies during laboratory exercises.

The decision to be taken by the managerial staff of the university concerning undertaking actions aimed at opening a major should depend first of all from the research personnel, secondly, from the laboratories and their equipment, thirdly, from the expenses to be borne in order to obtain a good quality of teaching.

Considering the abovementioned quantitative parameters (e.g. the number of hours, the hourly rate) and qualitative (the teaching level) it is to be stated that the teaching costs are not the only factor on which decisions made in a higher school depend. The cost amounts that are to be calculated as well as the qualitative factors give a complete value of didactic services.

A numerical example is presented below, which demonstrates the significance of the calculation of the basic decision-related factor, i.e. the cost of remuneration.

2.2. Estimation of teaching costs

The purpose of the estimation of costs is to determine which costs are to be taken into consideration when planning to open a new major.

In item 2.1, those costs were described which have a substantial impact on decisions related to plans to open a new major. The data concerning the following constitutes the components of staff costs related to conducting didactic class in a major:

- the number of didactic hours,
- the types of didactic classes,
- the hourly rates for those who conduct didactic classes.

$$Ko = \left[(Lh_w \cdot Gr_w \cdot A_w) + (Lh_c \cdot Gr_c \cdot A_c) + \left(Lh_p \cdot Gr_p \cdot A_p\right) + (Lh_l \cdot Gr_l \cdot A_l)\right] \cdot N \quad (1)$$

where:

Ko – the staff cost of the subject,
Lh_w – the number of lecture hours for the subject,
Lh_c – the number of exercise hours for the subject,
Lh_l – the number of laboratory groups for the subject,
Lh_p – the number of project hours for the subject,
Gr_w – the number of lecture groups,
Gr_c – the number of exercise groups,
Gr_l – the number of laboratory groups,
Gr_p – the number of project groups,
A_w, A_c, A_l, A_p – the hourly rate of a teacher who conducts: lectures, exercises, laboratories, projects,
N – the value which increases the costs of remuneration (benefits for employees: 30%), the constant: 1.3.

The personnel cost obtained from dependence (1) is the component of the cost of conducting the subject (2):

$$Kpp = Ko + (Ko \cdot C) \quad (2)$$

where:

Kpp – the cost of conducting a subject,
Ko – the personnel cost (gross remuneration + margins),
C – the proportion of the staff costs to the total costs 2/8 (the costs of maintaining rooms, laboratories, i.e.: energy, materials, external services, depreciation, apparatus).

On the basis of dependence (2), the cost of conducting a subject is calculated when accepting an estimated number of didactic hours. The data concerning the rates of remuneration are calculated on the basis of remuneration tables for those who are academic teachers as specified in the Decree by the Minister of Science and Higher Education concerning the terms and conditions of remuneration for work and granting other benefits related to work for those hired by a public university, dated 22 Dec. 2006 (Journal of Laws No. 251, Item 1852 from the year 2006). The results obtained from dependence (2) are presented in Table 1 on the example of a subject which is conducted on the major of "Information Technology" by the Department of Electronics and Information Technology at the Koszalin University of Technology. This subject is conducted during 44 hours. One professor, who conducts lectures, and an assistant lecturer, who conducts exercises, are involved in the subject. The didactic hours are divided into two types of didactic hours as follows: 22 hours of lectures and 22 hours of exercises. For the purpose of the calculations, it was accepted that the cost of the monthly gross remuneration of the professor will approximately be PLN 5,000, and the cost of the assistant lecturer will be PLN 2,800.

The remuneration multiplied by 12 months and divided by the teaching load gives the hourly rate of conducting the didactic classes. The teaching load is the number of the didactic hours conducted by an academic teacher during one academic year, which corresponds to the position occupied in the university in the said example: for the professor, 240 hours of the teaching load was accepted in the calculation of the rate, and 240 hours of the teaching load for the assistant lecturer for the calculation of the rate. The result was multiplied by the number of didactic hours, and then increased by 30 per cent. This increase involves the margins of the remuneration that constitute the costs that the employer has to bear when hiring a staff. These are national insurance contributions, the company's fund of social benefits and the fund of awards.

Tab. 1.

Components of the calculation of the costs of conducting a subject for the opening of a new major

Subject	No. of hours	Form of classes	No. of groups Grw/Grc	Lecturer's position	Rate for didactic hour Aw/Ac	Costs of remuneration	Staff costs Kow/Koc	Costs of conducting a subject Kpp
Analogue technology: signals and systems	44	22 lectures	1	professor	PLN 250	5 500	7 150	**28 958**
		22 exercises	4	assistant lecturer	PLN 140	12 320	16 016	

Source: Author's own study

The example presented above demonstrates the dependencies between the cost of remuneration and the data required for its calculation. It also demonstrates the possibility to calculate the total costs of conducting a subject. In order to calculate the cost of conducting a major, the subjects included in the curriculum are to be set; further, the number of hours, the forms of classes and the number of student groups are to be determined. Once these values have been obtained, the personnel is to be assigned to each subject; then, on the basis of a contract concluded with each member of the personnel, the hourly rate of the classes conducted can be determined.

The cost of conducting a major constitutes the total costs of the realization of the subject, which are set in the teaching standards, and are obtained in accordance with the following dependence:

$$Kpk = (Kpp_1 + Kpp_2 + Kpp_3 + \cdots + Kpp_i) \tag{3}$$

where:

Kpk – the cost of conducting the major,

Kpp_i – the cost of conducting the i^{th} subject.

What cost will be borne by the university when introducing the subject from the example?

The results of calculations obtained with the use of the model provide an answer to this question and all the other questions set above. They make it possible for those in charge of the university to take a decision concerning the majors that are open or closed.
One needs to remember before taking a decision concerning opening a new major or continuing an existing one that over 70 per cent of the cost of teaching a student involves remuneration and margins.

One also needs to remember it is not only numerical data concerning costs that is required to take managerial decisions. Several factors that are not measurable need to be considered. First of all, the product that is of an interest to us is to be determined, e.g. a new major; the data concerning the demand needs to be collected; a long-term forecast concerning the demand for a given major is to be set, and it needs to be determined how this will change in time.

Those in charge of the university should remember that the cost is a certain consequence of taking decisions concerning majors. For this reason, quick information concerning the cost will give the possibility to provide funds to cover this cost.

The precision data used in the example do not make it possible to determine the teaching costs in a situation when we deal with a plan. It does not include an answer to the following questions asked in universities:

- What will the university enrolment be like? – this constitutes the basis for the planning of finances in the didactic activity in compliance with the dependence as accepted in the example.
- How many student groups will there be?
- How many didactic hours will there be?

In planning, approximate values are to be accepted as it will never be possible to accurately foresee the enrolment numbers, which determines answers to questions: how many groups, how many hours.

For this reason, the model proposed to calculate the teaching costs includes an element of uncertainty in the form of fuzzy numbers.

The model proposed accepts the representation of knowledge in the form of the following pair: a set of decision variables and a set of relations that describe connections between decision variables. The model was formulated in the formalism of the theory of fuzzy sets.

According to dependence (2), budgets can be determined for specific didactic classes or individual majors. Fig. 1 presents the stages of the construction of the university's total costs, whose basic component is the wages budget:

- determining the proportion of the type of conducting of didactic classes for individual subjects,
- determining the costs of the wages budget for the subjects conducted in the unit,
- calculation of the costs for e.g. a department, a unit etc.
- calculation of the costs for a faculty,
- the total costs of the functioning of the university.

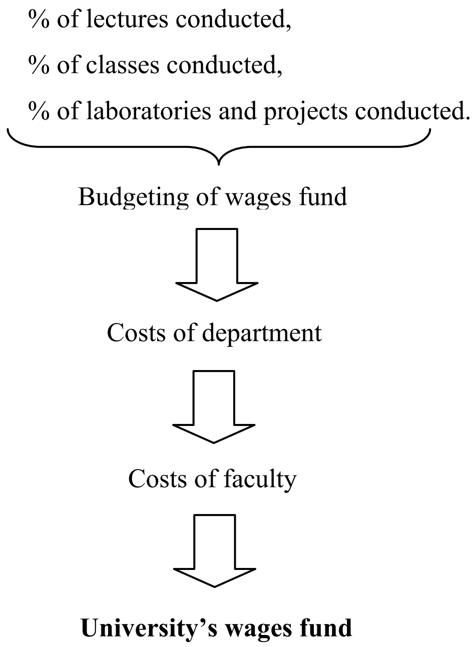

Fig. 1.: Settlement of university's wages fund

The wages fund is the basic component of costs that constitutes ca. 70 per cent of the budget. For this reason, it constitutes the basis for the construction of the budgeting model in the university.

The drawback of the model presented in Table 1 is that the data required for the calculation of the cost of conducting a subject is precise, whereas budgeting is based on non-precision data.

A plant involves data that is "circa", "not more than"; these terms are characteristic of fuzzy numbers; for this reason, an analysis of costs and the decision-making process connected with them determines the need to operate on non-precision data. This means that a construction of a system to facilitate a decision support through providing answers to a set of routine questions should be based on a model which takes into account an imprecise nature of the knowledge related to the process described.

3. Model of budgeting

In chapter 2, the method was presented to determine teaching costs based on precision data. However, in practice it is required on many occasions to make an estimation of costs without an accurate knowledge of some of the parameters. Therefore, it is necessary to build a model of costs which accepts an imprecise nature of the knowledge possessed. The approach proposed accepts a representation of knowledge in the form of a pair: a set of decision variables (which represent the costs and the parameters connected with them, e.g. Kpp, Ko etc.) and a set of relationships (e.g. dependences of the determination of costs (1), (2), (3) that describe the relationships between decision variables. This model and the problem connected with it is formulated in the formalism of the theory of fuzzy sets.

3.1. Fuzzy model

It was accepted that the model under elaboration includes the following:

- **fuzzy decision variables:**

$$\hat{V} = \{\hat{V}_1, \hat{V}_2, \ldots., \hat{V}_n\}$$

where:

$\hat{V}$	–	a finite set of fuzzy decision variables,
$\hat{V}_i$	–	i^{th} fuzzy decision variable.

$\hat{V}_i$ fuzzy variable is a variable that accepts imprecise values represented in the form of fuzzy numbers. A fuzzy number is a set of pairs described in a certain space of discussions X (1), (2):

$$\{(\mu(v), v)\}, \forall v \in X, \tag{4}$$

where:

μ	–	the membership function of the fuzzy number which assigns to each element
$v \in X$	–	the level of its membership
$\mu(v)$ t	–	o the fuzzy number, whereas: $\mu(v) \in (0,1)$.

Membership function μ realizes a representation of the space of discussions X of a given variable to range $(0,1)$: $\mu: X \rightarrow (0,1)$. The space of discussions is defined on the set of real numbers $X \subset \mathbb{R}$.

In the literature (8), (9), it is usually accepted that the fuzzy number (4) fulfills the following conditions:

1. $sup_{v \in X}\ \mu(v) = 1$, i.e. the fuzzy number (4) is normal,
2. $\mu(\lambda v_1 + (1-\lambda)v_2) \geq \min.\{\mu(v_1), \mu(v_2)\}$, i.e. the fuzzy number (4) is convex,
3. $\mu(v)$ is continuous through intervals.

The abovementioned assumptions apply to fuzzy numbers described in the space of real numbers $X \subset \mathbb{R}$. Further in the paper, it is also numbers described in those spaces that are subsets of natural numbers that will be taken into consideration. In the case of such numbers, the fulfillment of the "convexity" and "normality" conditions is assumed. Fig. 2 presents two fuzzy normal and convex numbers: a number described in the space of real numbers (continuous function $\mu(v)$): Fig. 2 a) and a number described in the space of natural numbers: Fig. 2 b).

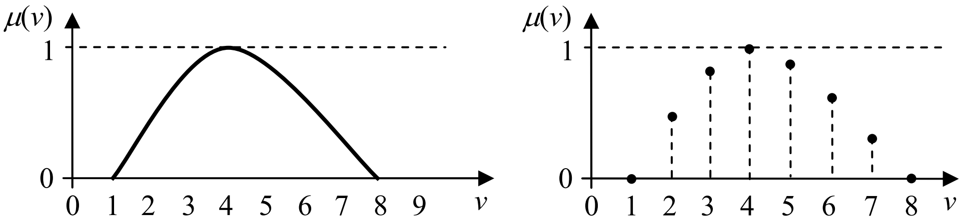

Fig.2.: Example fuzzy numbers:
a) described in $\mathbb{R}$ space, b) described in $\mathbb{N}$ space

The number from Fig. 2b is used for the description of values with a discrete nature. For example, if fuzzy number 2b specifies the number of student groups, in the coming academic year we may expect "*circa* 4" groups, not more than 8 and not fewer than 1.

The following was accepted in the context of the discussion above:

$$\hat{V}_i = \{(\mu_i(v), v)\}, \forall v \in X_i, \quad \hat{V}_i \in \hat{V} \tag{5}$$

which means that fuzzy variable $\hat{V}_i$ accepts an imprecise value that is determined by μ_i and X_i.

With the notion of the set of fuzzy decision variables $\hat{V}$, the notion is closely related with the family of the domain of variables $\widehat{M}$:

$$\widehat{M} = \{\widehat{M}_1, \widehat{M}_2, \dots., \widehat{M}_n\},$$

where:

$\widehat{M}_i$ – the domain of variable $\hat{V}_i$.

Domain $\widehat{M}_i$ is a set of fuzzy values that can be accepted by variable $\hat{V}_i$: $\hat{V}_i \in \widehat{M}_i$. It is accepted that $\widehat{M}_i$ is defined as follows:

$$\widehat{M}_i = \{\{(\mu(v), v)\} : \forall v \in X_i, \forall \mu \in \Theta_i\} \tag{6}$$

where:

X_i – the space of discussions being common for all the values of variable $\hat{V}_i$.

Θ_i – a set of the membership functions of the value of variable $\hat{V}_i$.

For example, a set of Gaussian functions with centre (m) from range $(1,10)$ and width (σ) from range $(1,2)$ has the following form:

$$\Theta_i = \left\{e^{-\left(\frac{v-m}{\sigma}\right)^2} : m \in [1,10], \ \sigma \in [1,2]\right\} \tag{7}$$

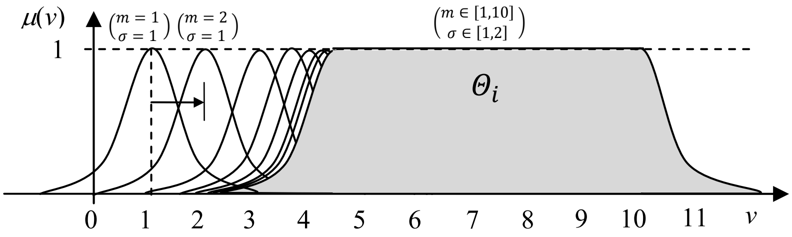

Fig. 3.: Example set of membership functions

The set of membership functions (4) is presented in Fig. 3. If we accept that Fig. 3 presents the domain of the cost of conducting a subject (in thousand Polish zloty), the fuzzy value of the variable is from the range from "ca. 1 thousand" to "ca. 10 thousand".

In compliance with the above, the domain of each variable $\widehat{M}_i$ is determined on the basis of a pair of the space of discussions X_i and the set of membership functions Θ_i, which will be represented by the representation of p:

$$\widehat{M}_i = p(X_i, \Theta_i). \quad (8)$$

- **relationships between fuzzy decision variables**:

$$\hat{R} = \{\hat{R}_1, \hat{R}_2, \dots, \hat{R}_m\}, \quad (9)$$

where:

$\hat{R}$ – a finite set of relationships between fuzzy decision variables,

$\hat{R}_i$ – i^{th} relationship.

Relationships describe connections between the values of specific fuzzy decision variables. A relationship between two fuzzy variables is the following fuzzy set:

$$\hat{R}_i = \{(\hat{\mu}_i(\hat{v}_a, \hat{v}_b), (\hat{v}_a, \hat{v}_b))\}, \forall \hat{v}_a \in \widehat{M}_a, \forall \hat{v}_b \in \widehat{M}_b, \quad (10)$$

$$\hat{\mu}_i: \hat{M}_a \times \hat{M}_b \to (0,1) \quad (11)$$

where:

- $\hat{v}_a, \hat{v}_b$ – the fuzzy numbers that are the elements of domains $\hat{M}_a$ and $\hat{M}_b$,
- $\hat{M}_a \times \hat{M}_b$ – the Cartesian product of domains $\hat{M}_a$ *and* $\hat{M}_b$.

Similarly as in the classical definition, the Cartesian product of domains with fuzzy elements is determined as a set of all the ordered pairs of the elements of these sets:

$$\hat{M}_a \times \hat{M}_b = \{(\hat{v}_a, \hat{v}_b): \forall \hat{v}_a \in \hat{M}_a, \forall \hat{v}_b \in \hat{M}_b\}, \quad (12)$$

$\hat{\mu}_i$ –the membership function of relationship $\hat{R}_i$ with fuzzy arguments. The value of membership function $\hat{\mu}_i(\hat{v}_a, \hat{v}_b)$ is to be interpreted as a degree of the fulfillment of relationship $\hat{R}_i$ for the arguments of $\hat{v}_a, \hat{v}_b$.

An example of relationship $\hat{R}_i$ can be constituted by a relationship that is described with the following statement: "variable $\hat{V}_a$ is smaller than variable $\hat{V}_b$"(e.g. cost $\hat{V}_a$ is smaller than the budget $\hat{V}_b$ possessed). Fig. 4 presents several possible values of variables $\hat{V}_a$, $\hat{V}_b$ and the value assigned to them of the fulfillment of relationship $\hat{R}_i$.

Fig. 4 a) presents a situation when the value of variable $\hat{V}_a$ is certainly smaller than the value of variable $\hat{V}_b$ (the cost is smaller than the budget). The membership functions of the values accepted do not intersect (the areas that are limited with curves do not possess any common parts), hence the value of the membership function of the relationship is 1: $\hat{\mu}_i(\hat{V}_a, \hat{V}_b) = 1$. At the same time, in the situations from Figures 4 b) and 4 c), the membership functions do not intersect any longer, i.e. there are certain values v which belong at the same time to $\hat{V}_a$ and $\hat{V}_b$. In such cases, relationship $\hat{R}_i$is not fulfilled for each value v (it seems that the cost is smaller than the budget: Fig. 4b, and almost certainly the cost is not smaller than the budget: Fig. 4c). In the last figure (Fig. 4d), it can be clearly seen that value $\hat{V}_a$is greater than value $\hat{V}_b$, hence relationship $\hat{R}_i$ is not fulfilled ($\hat{\mu}_i(\hat{V}_a, \hat{V}_b) = 0$) (the cost is certainly not smaller than the budget).

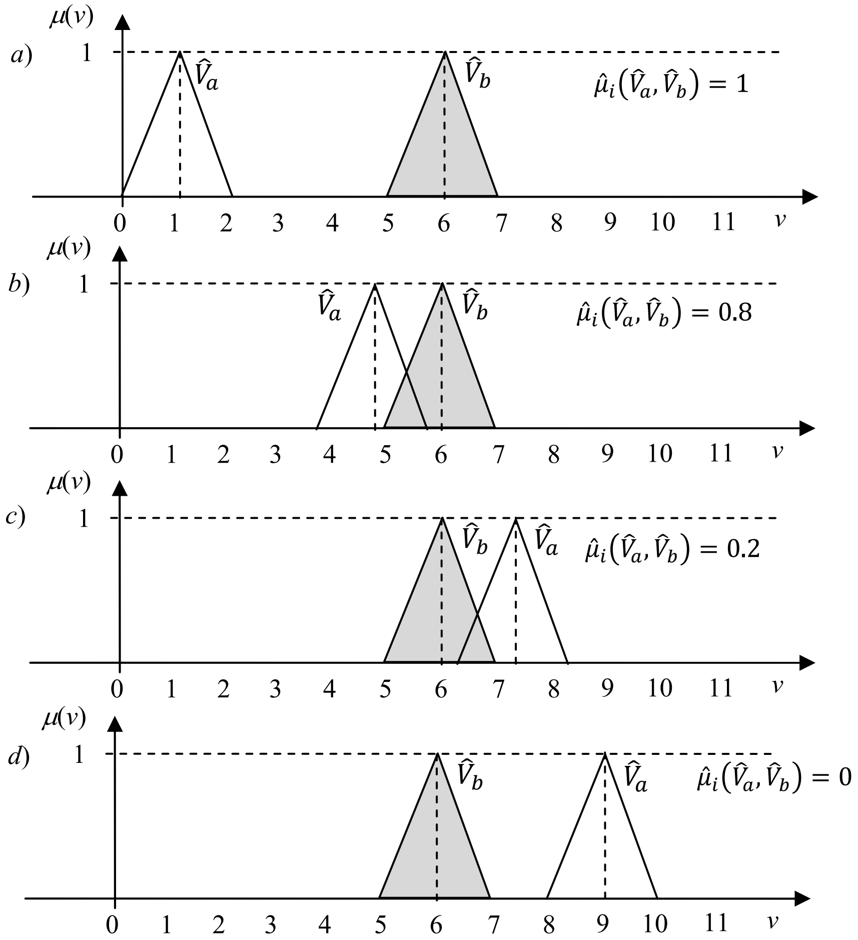

Fig.4.: Relationship "variable $\hat{V}_a$ is smaller than variable $\hat{V}_b$": a) $\hat{V}_a$ is smaller than $\hat{V}_b$, b) $\hat{V}_a$ is almost certainly smaller than $\hat{V}_b$, c) $\hat{V}_a$ is almost certainly not smaller than $\hat{V}_b$, d) $\hat{V}_a$ is not smaller than $\hat{V}_b$

To recapitulate the discussion above: a model can be fulfilled in the form of the following pair: a set of fuzzy decision variables $\hat{V}$ with a family of domains $\widehat{M}$ and a set of relationships $\hat{R}$. In the approach, the model takes on the following form:

$$FM = \left(\left(\hat{V}, \widehat{M}\right), \hat{R}\right). \qquad (13)$$

In the context of the model understood in this way, it is possible to formulate questions related to the search of the value of a specific subset of such decision variables that fulfill a given set of relationships.

3.2. Formulation of the problem

$FM = \left((\hat{V}, \hat{M}), \hat{R}\right)$ is given, which includes the following:

- a set of fuzzy decision variables $\hat{V}$, whose values are determined by $\hat{M}$,
- a set of fuzzy relationships $\hat{R}$ which determines the relationships between variables $\hat{V}$,

In set $\hat{V}$, two subsets of variables were distinguished:

$$\hat{U}, \hat{Y} \in \hat{V}, \quad \hat{U} \cap \hat{Y} = \emptyset.$$

A set of relationships $\hat{R}_{\hat{Y}}$ is given that describe relations between the variables of set $\hat{Y}$. The degree of the fulfillment of relationship S is given that is included in set $\hat{R} \cup \hat{R}_{\hat{Y}}$.

An answer is sought to the following question:

Are there such values of variables $\hat{U}$, for which the relationships included in set $\hat{R} \cup \hat{R}_{\hat{Y}}$ will be fulfilled in a given degree S?

Seeking of such values $\hat{U}$ for which the degree of the fulfillment of the relationships included in set $\hat{R} \cup \hat{R}_{\hat{Y}}$ will be on a given degree S means seeking such values for which membership function $\hat{\mu}_i$ of each relationship of set $\hat{R} \cup \hat{R}_{\hat{Y}}$ takes a value which is at least S.

Distinguishing in the set the decision variables of sets $\hat{U}$ and $\hat{Y}$ means that FM can be perceived as an "input – output" system (Fig. 5).

- "Input" $\hat{U}$ is a set of such variables whose values are not known, and which we want to know.
- „Output" $\hat{Y}$ is a set of such variables which are not known and for which a set of relationships $\hat{R}_{\hat{Y}}$ is given that specifies

additional relationships between them. In particular, relationships $\widehat{\mathrm{R}}_{\widehat{\mathrm{Y}}}$ can be relationships of an assignment to the variables of specific values. In such circumstances we can say that the values of variables $\widehat{\mathrm{Y}}$ are known.

In this approach, the problem presented involves seeking such an "input" $\widehat{U}$of FM system that will guarantee obtaining "*output*" $\widehat{Y}$ that fulfills a given set of relationships $\widehat{R}_{\widehat{Y}}$. In other words, in the context of a given object, the "*reason*" is sought that guarantees a specific "*result*".

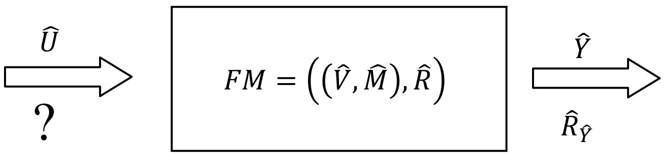

Fig.5.: FM as in input/output set

It is to be noted that unlike this type of problems that are dealt with in the literature (8), an imprecise (fuzzy) nature of both decision variables and relationships that connect individual variables is accepted in the problem under consideration. In this way, the solutions sought can "more" or "less" fulfill the assumptions given. This means that a decision maker may on his own determine the limits of the space of solutions through the definition of the degree of the acceptation of individual solutions.

3.3. L-R representation

The problem presented in Chapter 3.2 connected with the FM model (10) is of an overall nature. Depending of the accepted class of decision variables $\widehat{V}$ and relationships $\widehat{R}$, it can be made more specific and can be used in different decision support areas. In this chapter, a particular case was presented of the FM model that is dedicated to the problem of the calculation of the costs of conducting subjects. The precision consists in accepting $L - R$ representation of fuzzy values and a determination in this representation the form of the relationships corresponding to algebraic operations. In particular, the following is accepted in this model:

- the values of fuzzy decision variables $\hat{V}_i \in \hat{V}$ are described with the aid of the L-R (8) representation. This representation represents fuzzy numbers with the aid of 4 parameters:

$$(m_1, m_2, \alpha, \beta)_{LR}, \tag{14}$$

where:

$[m_1, m_2]$	–	a range referred to as the core [9] of the fuzzy number, the value of the membership function in this range is 1: $\mu(v) = 1, \forall v \in [m_1, m_2]$
m_1, m_2	–	the lower and upper limits of the core,
α, β –	–	the range of the left and right slopes of the fuzzy number.

The four presented (11) determines the parameters of the so-called L and R mapping functions. L and R mapping functions are such that: $L(0) = R(0) = 1$; $L(1) = R(1) = 0$. The membership function of a fuzzy number is defined as follows:

$$\mu(v) = \begin{cases} L\left(\frac{m_1 - v}{\alpha}\right), & \text{when } v < m_1 \\ 1, & \text{when } v \in [m_1, m_2] \\ R\left(\frac{m_2 - v}{\alpha}\right), & \text{when } v > m_1 \end{cases} \tag{15}$$

It was accepted that L and R are linear functions.This means that membership functions accept triangular or generally trapezoidal shapes. Fig. 6 presents an example of a description of a triangular number and a trapezoidal (flat) number.

The assumption of a trapezoidal shape of the membership function for each value of decision variables $\hat{V}_i$ determines the form of the set of membership functions Θ_i. A set of membership functions Θ_i which includes trapezoidal functions only, will further be determined by Π_i.

This means that the domain of a fuzzy variable in L-R mapping is determined similarly to (5) as the following function:

$$\hat{M}_{LR,i} = p(X_i, \Pi_i) \,. \tag{16}$$

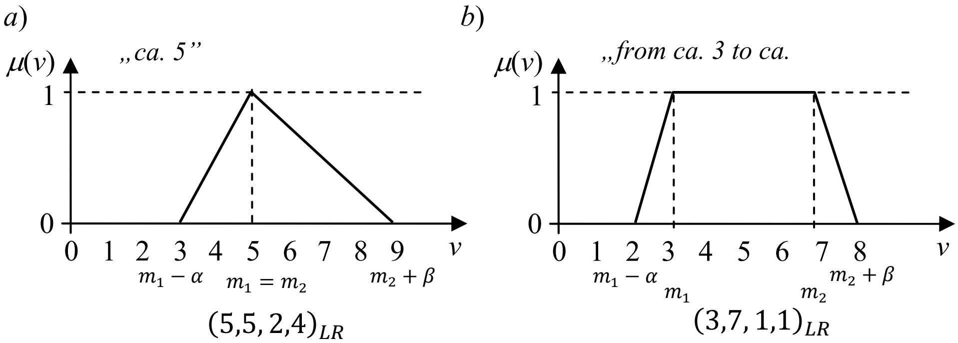

Fig.6.: Description of fuzzy numbers in LR mapping,
a) "ca. 5", b) "from ca. 3 to ca. 7"

In particular, $\widehat{M}_{LR,i}$ is a set of fours that represent fuzzy numbers included in the following domain:

$$\widehat{M}_{LR,i} = \{(m_1, m_2, \alpha, \beta)_{LR} : m_1, m_2, \alpha, \beta \in X_i\}, \tag{17}$$

where:

X_i – the space of discussions of variable $\widehat{V}_i$.

In this context, the family of domains for the L-R representation, similarly as $\widehat{M}$, takes on the following form:

$$\widehat{M}_{LR} = \{\widehat{M}_{LR,1}, \widehat{M}_{LR,2}, \dots, \widehat{M}_{LR,n}\}. \tag{18}$$

- a set of relationships $\hat{R}$ includes algebraic relationships only (described with the use of operators: "+", "-", "/", "·", "=", "<", ">", "≤", "≥"). The following expression is an example of such a relationship:

$$\hat{R}_i : \widehat{V}_1 + 2\cdot\widehat{V}_2 = \widehat{V}_3. \tag{19}$$

This is an example of an equivalence relation, where the result of the sum $\widehat{V}_1 + 2\cdot\widehat{V}_2$ is compared with the value of variable $\widehat{V}_3$. The result of the relation is a set of the values of variables $\widehat{V}_1, \widehat{V}_2, \widehat{V}_3$, for which the membership function of set $\hat{R}_i$ fulfills: $\hat{\mu}_i > S_i$, where: S_i is the acceptation degree of relation $\hat{R}_i$.

Definitions of algebraic operations are required for the construction of this type of relations. For the representation of *L-R* (8) :

- sum „$\hat{+}$” of two fuzzy numbers $(\hat{V}_1, \hat{V}_2)$ is defined as follows:

$$\hat{V}_3 = (\hat{V}_1 \hat{+} \hat{V}_2) = (m_{1,V_3}, m_{2,V_3}, \alpha_{V_3}, \beta_{V_3})_{LR} \tag{20}$$

where:

$$\hat{V}_1 = (m_{1,V_1}, m_{2,V_1}, \alpha_{V_1}, \beta_{V_1})_{LR},$$
$$\hat{V}_2 = (m_{1,V_2}, m_{2,V_2}, \alpha_{V_2}, \beta_{V_2})_{LR},$$
$$m_{1,V_3} = m_{1,V_1} + m_{1,V_2}, m_{2,V_3} = m_{2,V_1} + m_{2,V_2},$$
$$\alpha_{V_3} = \alpha_{V_1} + \alpha_{V_2},\ \beta_{V_3} = \beta_{V_1} + \beta_{V_2},$$

- difference „$\hat{-}$” of two fuzzy numbers $(\hat{V}_1, \hat{V}_2)$ is defined as follows:

$$\hat{V}_3 = (\hat{V}_1 \hat{-} \hat{V}_2) = (m_{1,V_3}, m_{2,V_3}, \alpha_{V_3}, \beta_{V_3})_{LR} \tag{21}$$

where:

$$\hat{V}_1 = (m_{1,V_1}, m_{2,V_1}, \alpha_{V_1}, \beta_{V_1})_{LR},$$
$$\hat{V}_2 = (m_{1,V_2}, m_{2,V_2}, \alpha_{V_2}, \beta_{V_2})_{LR},$$
$$m_{1,V_3} = m_{1,V_1} - m_{1,V_2}, m_{2,V_3} = m_{2,V_1} - m_{2,V_2},$$
$$\alpha_{V_3} = \alpha_{V_1} + \beta_{V_2},\ \beta_{V_3} = \alpha_{V_2} + \beta_{V_1},$$

- product „$\hat{\cdot}$” of two positive fuzzy numbers $(\hat{V}_1, \hat{V}_2)$ is defined as follows:

$$\hat{V}_3 = (\hat{V}_1 \hat{\cdot} \hat{V}_2) = (m_{1,V_3}, m_{2,V_3}, \alpha_{V_3}, \beta_{V_3})_{LR} \tag{22}$$

where:

$$\hat{V}_1 = (m_{1,V_1}, m_{2,V_1}, \alpha_{V_1}, \beta_{V_1})_{LR},$$
$$\hat{V}_2 = (m_{1,V_2}, m_{2,V_2}, \alpha_{V_2}, \beta_{V_2})_{LR},$$
$$m_{1,V_3} = m_{1,V_1} \cdot m_{1,V_2}, m_{2,V_3} = m_{2,V_1} \cdot m_{2,V_2},$$

$\alpha_{V_3} = m_{1,V_1} \cdot \alpha_{V_2} + m_{1,V_2} \cdot \alpha_{V_1} - \alpha_{V_2} \cdot \alpha_{V_1},\ \beta_{V_3} = m_{2,V_1} \cdot \beta_{V_2} + m_{2,V_2} \cdot \beta_{V_1} - \beta_{V_2} \cdot \beta_{V_1},$

- quotient „$\hat{/}$" of two positive fuzzy numbers $(\hat{V}_1, \hat{V}_2)$ is defined as follows:

$$\hat{V}_3 = (\hat{V}_1 \hat{/} \hat{V}_2) = (m_{1,V_3}, m_{2,V_3}, \alpha_{V_3}, \beta_{V_3})_{LR} \tag{23}$$

where:

$$\hat{V}_1 = (m_{1,V_1}, m_{2,V_1}, \alpha_{V_1}, \beta_{V_1})_{LR},$$
$$\hat{V}_2 = (m_{1,V_2}, m_{2,V_2}, \alpha_{V_2}, \beta_{V_2})_{LR},$$
$$m_{1,V_3} = m_{1,V_1}/m_{1,V_2},\ m_{2,V_3} = m_{2,V_1}/m_{2,V_2},$$
$$\alpha_{V_3} = \frac{m_{1,V_1} \cdot \beta_{V_2} + m_{1,V_2} \cdot \alpha_{V_1}}{m_{1,V_2} \cdot (m_{1,V_2} - \beta_{V_2})}, \beta_{V_3} = \frac{m_{2,V_1} \cdot \beta\alpha_{V_2} + m_{2,V_2} \cdot \beta_{V_1}}{m_{2,V_2} \cdot (m_{2,V_2} - \alpha_{V_2})}$$

Equivalence and minority relations (1) are defined as follows:

- majority relation $\hat{R}_i$: $\hat{V}_1 \hat{=} \hat{V}_2$, whose degree of fulfillment is:

$$\hat{\mu}_i(\hat{V}_1, \hat{V}_2) = \frac{2S^*}{S_1 + S_2}, \tag{24}$$

where:

- S_1 – the size of a fuzzy number that is the value of variable $\hat{V}_1$. The size is calculated as the area of the surface limited by the curve of the membership grade $\hat{\mu}_1(v)$,
- S_2 – the size of a fuzzy number that is the value of variable $\hat{V}_2$. The size is calculated as the area of the surface limited by the curve of the membership grade $\hat{\mu}_2(v)$,
- S^* – the size of the common part of those fuzzy numbers which constitute values $\hat{V}_1$ and $\hat{V}_2$. Size S^* is calculated as the area of the surface limited by the curves of the membership grade $\hat{\mu}_1(v)$, $\hat{\mu}_2(v)$.

- minority relation $\hat{R}_i$: $\hat{V}_1 \hat{<} \hat{V}_2$; the fulfillment degree is as follows:

$$\hat{\mu}_i(\hat{V}_1, \hat{V}_2) = \frac{S_1{}^L + S_2{}^P}{S_1 + S_2}, \tag{25}$$

where:

- S_1 – the size of the fuzzy number that is the value of variable $\hat{V}_1$,
- S_2 – the size of the fuzzy number that is the value of variable $\hat{V}_2$,
- $S_1{}^L$ – the area of the surface limited by the curve of the membership degree $\hat{\mu}_1(v)$ reduced by the area of the surface of common part S^*,
- $S_2{}^P$ – the area of the surface limited by the curve of the membership degree $\hat{\mu}_2(v)$ reduced by the area of the surface of common part S^*.

The set of relationships of an algebraic nature constructed with the use of the operators presented will be marked as follows:

$$\hat{R}_{LR} = \{\hat{R}_{LR,1}, \hat{R}_{LR,2}, \dots, \hat{R}_{LR,m}\}. \tag{26}$$

In the context of the discussion above, the L-R model takes on the following form:

$$MK = \left((\hat{V}, \hat{M}_{LR}), \hat{R}_{LR}\right) \tag{27}$$

Similarly as in the FM model, for the MK model (21), the following problem is considered:

$MK = \left((\hat{V}, \hat{M}_{LR}), \hat{R}_{LR}\right)$ is given, which includes the following:

- a set of fuzzy decision variables $\hat{V}$, whose values in the L-R representation are determined by $\hat{M}_{LR}$
- a set of fuzzy relationships $\hat{R}_{LR}$ which determines algebraic relations between variables $\hat{V}$.

In set $\hat{V}$, two subsets of variables are distinguished:

$$\hat{U}, \hat{Y} \in \hat{V}, \quad \hat{U} \cap \hat{Y} = \emptyset.$$

A set of relations $\hat{R}_{LR\hat{Y}}$ is given that describe relationships between the variables of set $\hat{Y}$. The degree of fulfillment S is given of the relationships included in set $\hat{R}_{LR}$ and the degree of fulfillment $S_{\hat{Y}}$ of the relationships included in set $\hat{R}_{LR\hat{Y}}$.

An answer is sought to the following question:
Are there such values of variables $\hat{U}$ for which relations included in set $\hat{R}_{LR}$ will be fulfilled in a given degree S and relations $\hat{R}_{LR\hat{Y}}$ will be fulfilled in a given degree $S_{\hat{Y}}$?

Unlike the overall problem in this case, the search of the values of variables $\hat{U}$ is understood to be the search of the values of those parameters (14) that represent a fuzzy number. Seeking parameters and not membership functions alone brings down the problem to the one where variables take on precision values (parameters (14) are understood as variables in this case). Therefore, the problem presented may be brought down to the form of the problem of fulfilling *PSO* constraints, where variables constitute parameters of the membership function of the values of fuzzy variables $\hat{V}$:

$$PS = \big((V_{LR}, D_{LR}), C_{LR}\big), \tag{28}$$

where:

- V_{LR} – set of variables m_1, m_2, α, β that represent the values of fuzzy variables $\hat{V}$
- D_{LR} – a family of the domains of those variables that determine the permissible values of variables m_1, m_2, α, β; it is accepted that the domains are equal to the spaces of discussions X_i.
- C_{LR} – a set of those constraints that represent the degree of the fulfillment of relationship $\hat{R}_{LR}$ and $\hat{R}_{LR\hat{Y}}$. The constraints take on the form of the following inequality: $\hat{\mu}_i(V_{LR}) \geq S$ for the relationship of set $\hat{R}_{LR}$ and $\hat{\mu}_i(V_{LR}) \geq S_{\hat{Y}}$ for the relationship of set $\hat{R}_{LR\hat{Y}}$, where $\hat{\mu}_i$ is the function that determines the degree of the fulfillment of relationship $\hat{R}_i$.

Obtaining an answer to the question asked is brought down to the solution of the problem of the fulfillment of constraints (21).

4. Calculation examples

The examples presented serve to illustrate the use of the MK model to determine the values of the parameters connected with the cost of conducting the subject of Analogue Technology: Signals and Systems. The purpose of the first example is to illustrate the determination of the number of didactic groups with a budget that is known. The purpose of the second example is to illustrate the determination of the cost of conducting the subject of Analogue Technology: Signals and Systems.

4.1. A "backwards" example

The purpose of this example is to illustrate the determination, on the basis of the model proposed, the number of student groups that determines the costs of conducting of a subject that do not exceed a given level of the budget.

The determination of the number of groups concerns the subject of Analogue Technique: Signals and Systems. This subject is foreseen for 44 hours of didactic classes including 22 hours of lectures and 22 hours of exercises. All the factors are known which have an impact on the cost: apart from the number of groups (lecture and exercise groups). The cost of conducting the subject should fit in the budget given amounting to "ca. 30,000 zloty". In this context, an answer is sought to the following question:
Is there such a number of didactic groups which determines obtaining of the cost of conducting the subject of "ca. 30,000 zloty"?

The problem considered has a nature of a "backwards" type. For a given value of the cost, the values of those parameters that guarantee this cost are sought. Due to the uncertainty concerning the real number of newly created student groups after the foreseen enrolment for another academic year, it is required to use a fuzzy model. For this purpose, the MK model (26) was used. In this model, the following set of fuzzy decision variables was accepted $\hat{V}$:

$$\hat{V} = \{\widehat{Ko}_w, \widehat{Ko}_c, \widehat{Ko}, \widehat{Kpp}, \widehat{Lh}_w, \widehat{Lh}_c, \widehat{Gr}_w, \widehat{Gr}_c, \hat{A}_w, \hat{A}_c, \hat{C}_1, \hat{C}_2, \hat{N}_{w1}, \hat{N}_{w2}\}, \quad (29)$$

where:

- $\widehat{Ko}_w$ – the fuzzy staff cost of the lectures,
- $\widehat{Ko}_c$ – the fuzzy staff cost of the exercises,
- $\widehat{Ko}$ – the fuzzy staff cost of conducting the subject,

$\widehat{Kpp}$	–	the fuzzy cost of conducting the subject,
$\widehat{Lh}_w$	–	the fuzzy number of lecture hours for the subject,
$\widehat{Lh}_c$	–	the fuzzy number of exercise hours for the subject,
$\widehat{Gr}_c$	–	the fuzzy number of exercise groups,
$\widehat{Gr}_w$	–	the fuzzy number of lecture groups,
$\hat{A}_w$	–	the fuzzy hourly rate of the teacher who conducts the lectures,
$\hat{A}_c$	–	the fuzzy hourly rate of the teacher who conducts the classes,
$\hat{C}_1, \hat{C}_2$	–	the constant proportionalities of the staff costs to the total costs,
$\widehat{N}_{w1}, \widehat{N}_{w2}$	–	the value which increases the costs of remuneration and margins connected with remuneration.

Variables $\hat{V}$ represent the individual costs as well as the required components for their calculation (in compliance with dependence (1)).

The descriptive relations and the values of costs depend from specific parameters and are formulated in the form of relationship $\hat{R}_{LR}$.

The relations which describe the connections between the value of the cost of conducting the subject $\widehat{Kpp}$ and the remaining variables take on the following form:

$$\hat{R}_{LR} = \{\hat{R}_{LR,1}, \hat{R}_{LR,2}, \hat{R}_{LR,3}, \hat{R}_{LR,4}\}, \tag{30}$$

where:

$$\hat{R}_{LR,1}\colon\ \widehat{Kpp} \cdot \hat{C}_2 = \widehat{Ko} \cdot \hat{C}_1 \tag{31}$$

$$\hat{R}_{LR,2}\colon\ \widehat{Ko} = \widehat{Ko}_w + \widehat{Ko}_c \tag{32}$$

$$\hat{R}_{LR,3}\colon\ \widehat{Ko}_c \cdot \widehat{N}_{w1} = \widehat{Lh}_c \cdot \widehat{Gr}_c \cdot \hat{A}_c \cdot \widehat{N}_{w2} \tag{33}$$

$$\hat{R}_{LR,4}\colon\ \widehat{Ko}_w \cdot \widehat{N}_{w1} = \widehat{Lh}_w \cdot \widehat{Gr}_w \cdot \hat{A}_w \cdot \widehat{N}_{w2} \tag{34}$$

Relations (31)-(34) constitute a generalized form of dependences (1)-(2) (which takes into account the imprecise nature of the variables) (1)-(2).

In compliance with the assumptions of the MK model, in the set of decision variables $\hat{V}$, input variables $\hat{U}$ and output variables $\hat{Y}$ were distinguished. Those variables that determine the number of student groups $\widehat{Gr_w}, \widehat{Gr_c}$ form a set of input variables $\hat{U}$ while the remaining variables: $\widehat{Kpp}, \widehat{Ko_w}, \widehat{Ko_c}, \widehat{Ko}, \hat{A}_w, \hat{A}_c, \hat{C}_1, \hat{C}_2, \hat{N}_{w1}, \hat{N}_{w2}$ form output variables $\hat{Y}$.

For output variables, relationships $\hat{R}_{LR\hat{Y}}$ are known which assign to the variables the values of these variables (margin values, proportionality factors, hourly rates etc.):

$$\hat{R}_{LR\hat{Y},3}: \widehat{Lh}_c = (22,22,0,0)_{LR} \tag{35}$$

$$\hat{R}_{LR\hat{Y},4}: \widehat{Lh}_w = (22,22,0,0)_{LR} \tag{36}$$

$$\hat{R}_{LR\hat{Y},5}: \hat{A}_w = (250,250,0,0)_{LR} \tag{37}$$

$$\hat{R}_{LR\hat{Y},6}: \hat{A}_c = (140,140,0,0)_{LR} \tag{38}$$

$$\hat{R}_{LR\hat{Y},7}: \hat{N}_{w1} = (13,13,0,0)_{LR} \tag{39}$$

$$\hat{R}_{LR\hat{Y},8}: \hat{N}_{w2} = (10,10,0,0)_{LR} \tag{40}$$

$$\hat{R}_{LR\hat{Y},9}: \hat{C}_1 = (10,10,0,0)_{LR} \tag{41}$$

$$\hat{R}_{LR\hat{Y},10}: \hat{C}_2 = (8,8,0,0)_{LR} \tag{42}$$

$$\hat{R}_{LR\hat{Y},11}: \widehat{Kpp} = (30000,30000,10000,10000)_{LR} \tag{43}$$

All the variables with the exception of $\widehat{Kpp}$ accept precision values represented in the form of singletons.

It is to be noted that the relationships that occur both in $\hat{R}_{LR}$ and $\hat{R}_{LR\hat{Y}}$ sets accept the form of "equivalent" relationships whose fulfillment degree $\hat{\mu}_i$ is defined by (24).

In the context of a model defined in this manner, the question concerning the number of didactic groups for the subject of Analogue Technique: Signals and Systems is as follows:

Are there such values of variables $\widehat{U}$ (the number of didactic groups $\widehat{Gr}_w, \widehat{Gr}_c$), for which the relationships included in the set and the relationships from set $\widehat{R}_{LR\widehat{Y}}$ will certainly be fulfilled?

Providing an answer to such a question involves a representation of the MK model as a problem to fulfill PS constraints (28) and solving it with the use of the technologies of programming with constraints (Oz Mozart environment (11)). The set of solutions obtained included only one permissible solution. The number of lecture and exercise groups is as follows:

$$\widehat{R}_{LR\widehat{Y},1}\colon\ \widehat{Gr}_w = (1,1,0,0)_{LR} \tag{44}$$

$$\widehat{R}_{LR\widehat{Y},2}\colon \widehat{Gr}_c = (4,4,1,1)_{LR} \tag{45}$$

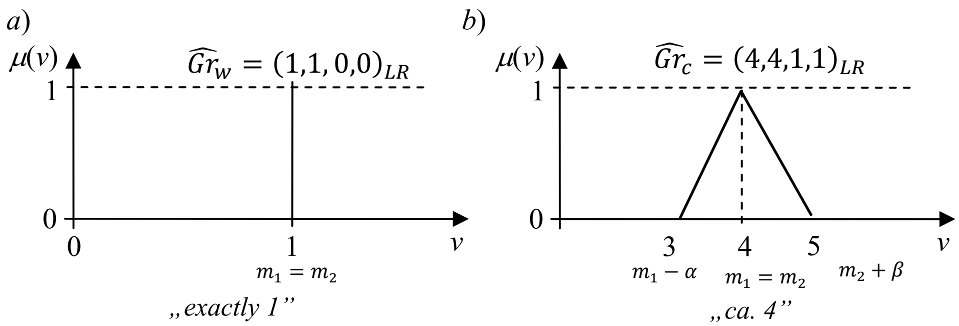

Fig.7.: Number of lecture groups $\widehat{G}_{rw}$
a) and exercise groups $\widehat{G}_{rc}$ b) in L-R representation

With $\widehat{Gr}_w$ number of lecture groups "exactly *1*" and of exercise groups $\widehat{Gr}_c$ "*ca. 4*", the cost of conducting the subject ($\widehat{Kpp}$) is between 23953 and 33963 (cf. Fig. 8d).

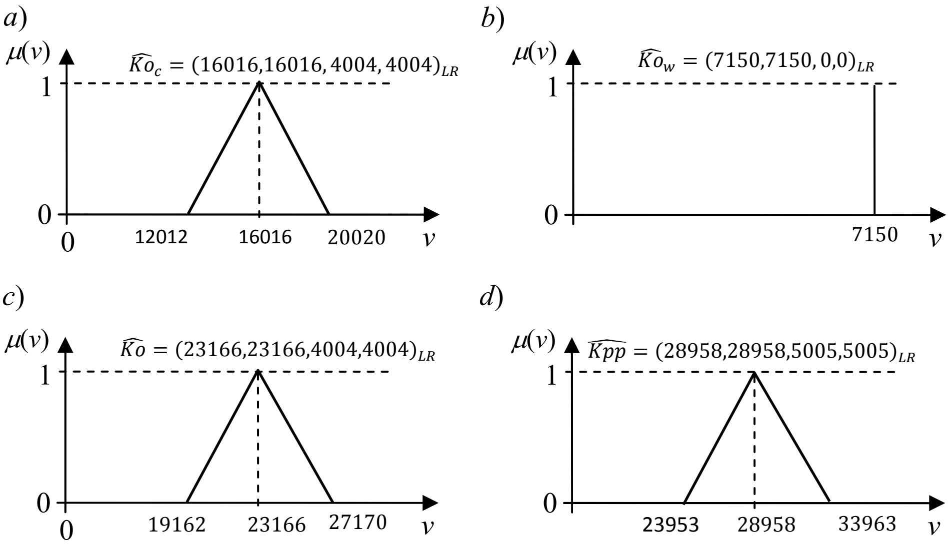

Fig. 8.: The costs of conducting the subject:
a) the staff cost of the exercises, b) the staff cost of the exercises, c) the staff cost of conducting the subject, d) the total costs of conducting the subject

Owing to the determination of the didactic groups in the form of fuzzy numbers it is possible to establish the range of costs that can be achieved. With the budget given of "ca. 30,000" zloty, 1 lecture group and "ca. 4" exercise groups are to be created. If we create 5 exercise groups, we will exceed the budget by 3,963, and with three exercise groups there are some savings. In general, each cost component $\widehat{Kpp}$ may accept fuzzy values in a specific space of discussions with an assigned degree of certainty.

4.2. "Forwards" example

The purpose of the present example is to illustrate the determination of the value of the cost of conducting the subject of Analogue Technique: Signals and Systems with the fuzzy values of the number of student groups known. The subject is foreseen to involve 44 hours of didactic classes including 22 hours in the form of lectures and 22 hours in the form of exercises. The hourly rate for the lecture is 250, and the hourly rate for exercises is 140. The number of the exercise groups is specified to be "ca. 12", and the number of the lecture groups to be "not more than 2". In this context, an answer is sought to the following question:

What will be the cost of conducting the subject of Analogue Technique: Signals and Systems?

The problem under consideration is of a "forwards" nature. The value of the cost is sought, which is implied by the given values of the parameters.

Similarly as in the "backwards" example, obtaining an answer to the question involves a formulation of the MK fuzzy model of the calculation of costs. In this model, the same set was accepted of decision variables $\hat{V}$ (29) and the set of relationships $\hat{R}_{LR}$ (30).

As opposed to the "backwards" example, the set of input variables $\hat{U}$ includes cost variable $\widehat{Kpp}$, whereas the set of output variables $\hat{Y}$ includes the following variables: $\widehat{Gr}_w, \widehat{Gr}_c, \hat{A}_w, \hat{A}_c, \hat{C}_1, \hat{C}_2, \hat{N}_{w1}, \hat{N}_{w2}$.

For the output variables, relationships $\hat{R}_{LR\hat{Y}}$ which assign their values to the variables taken on the following form:

$$\hat{R}_{LR\hat{Y},1}: \widehat{Lh}_c = (22,22,0,0)_{LR} \tag{46}$$

$$\hat{R}_{LR\hat{Y},2}: \widehat{Lh}_w = (22,22,0,0)_{LR} \tag{47}$$

$$\hat{R}_{LR\hat{Y},3}: \hat{A}_w = (250,250,0,0)_{LR} \tag{48}$$

$$\hat{R}_{LR\hat{Y},4}: \hat{A}_c = (140,140,0,0)_{LR} \tag{49}$$

$$\hat{R}_{LR\hat{Y},5}: \hat{N}_{w1} = (13,13,0,0)_{LR} \tag{50}$$

$$\hat{R}_{LR\hat{Y},6}: \hat{N}_{w2} = (10,10,0,0)_{LR} \tag{51}$$

$$\hat{R}_{LR\hat{Y},7}: \hat{C}_1 = (25,25,0,0)_{LR} \tag{52}$$

$$\hat{R}_{LR\hat{Y},8}: \hat{C}_2 = (100,100,0,0)_{LR} \tag{53}$$

$$\hat{R}_{LR\hat{Y},9}: \widehat{Gr}_{\mathrm{w}} = (2,2,1,0)_{LR} \tag{54}$$

$$\hat{R}_{LR\hat{Y},10}: \widehat{Gr}_c = (12,12,4,2)_{LR} \tag{55}$$

In the context of the model defined in this manner, the question is as follows: *Are there such values of variables $\widehat{U}$ (the cost of conducting the subject $\widehat{Kpp}$) for which the relationships included in set $\hat{R}_{LR}$ and the relationships from set $\hat{R}_{LR\hat{Y}}$ will certainly be fulfilled*?

Providing an answer to this question involves a solution of the problem of the fulfillment of PS constraints that corresponds to the MK model formulated. The solution obtained (the values of cost $\widehat{Kpp}$ and $\widehat{Ko}_w, \widehat{Ko}_c, \widehat{Ko}$) is illustrated in Fig. 9.

For the given values of parameters (46)-(55), the value obtained of the cost of conducting the subject is in the range of 48978-87945 ("ca. 69000"). This is such information that facilitates taking a decision concerning introducing the subject to the curriculum of the studies.

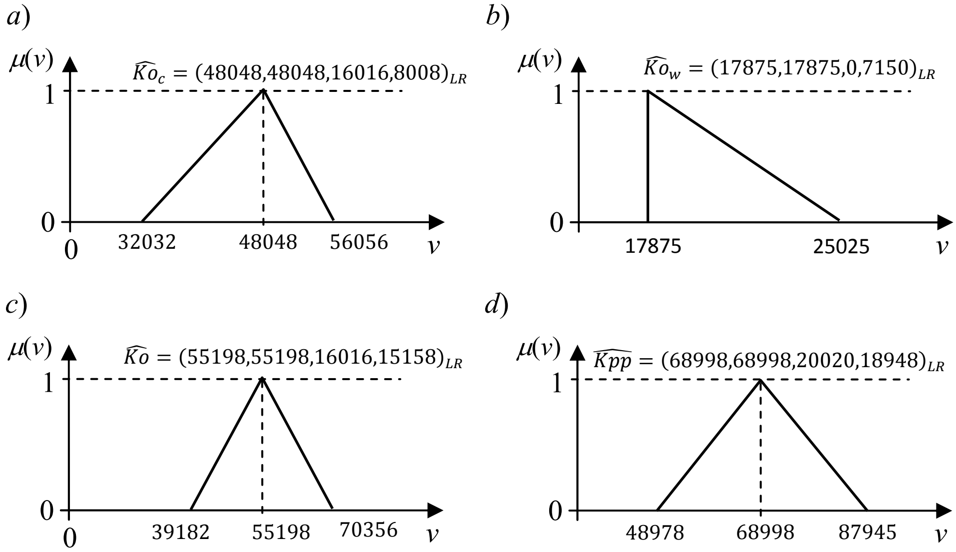

Fig. 9.: Costs of conducting the subject:
a) the staff cost of the exercises, b) the staff cost of the exercises, c) the staff cost of conducting the subject, d) the total cost of conducting the subject

4.3. Conclusions

The examples presented above prove the fact that with imprecise input data it is possible to calculate the cost of conducting the subject in a specific range. An imprecise nature of input data determines an imprecise nature of the cost of conducting the subject. This means that this model allows one to answer the questions asked with planned data.

The first example demonstrates the application of the calculation model of the teaching cost through backward forecasting. It shows a situation when data is determined with the budget known and a verification is made as to whether this budget will not be exceeded. This gives a possibility to specify those parameters that have an impact on the cost. This is also a mechanism which provides an answer to the following question: are there such parameters that prevent one from exceeding a specific level of costs?

The second example provides an answer as to what value of the costs can be achieved with specific data that has an impact on their amount. This allows one to estimate costs before they are incurred on the basis of imprecise data, which cannot be accurately estimated on the stage of planning.

5. Conclusions

The calculation model of teaching costs based on fuzzy numbers has filled the gap concerning the lack of strategic information. For this reason, the proposal addressed to the university in the form of a model of a cost statement that is based on imprecise data meets the needs of managers. This model offers a possibility to answer questions concerning the cost of the subject, major, unit and the whole university related to the teaching of students and graduates. It facilitates forecasting with the aid of imprecise data and allows one to introduce historic (precision) data, owing to which it is possible to control the plan with its execution. The deviations occurring serve as an indication and enable one to make the input data more precise as the degree of the imprecision of input data determines the imprecision of output data.

The advantage of this model is the possibility for those in charge of the university to promptly obtain information (through the use of the techniques of programming with constraints) concerning the value of the costs for a specified period of time for the purpose of the valuation of the student cost. In general, it allows one to answer questions concerning the value of costs, and also constitutes the basis for answers concerning each variable from which the total cost depends.

The cost calculation model does not offer a possibility to evaluate an impact of the creation of new majors on the costs of conducting those majors that already exist. The L-R representation with a description of fuzzy variables allows one to solve problems on a scale that is found in practice. Nevertheless, its drawback is that it allows one only to use descriptions of fuzzy variables with the aid of trapezoidal membership functions.

Further research should cover an extension of the model to obtain a greater functionality concerning a comparison of historical data with the forecast obtained through the mapping of the uncertainty factor.

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