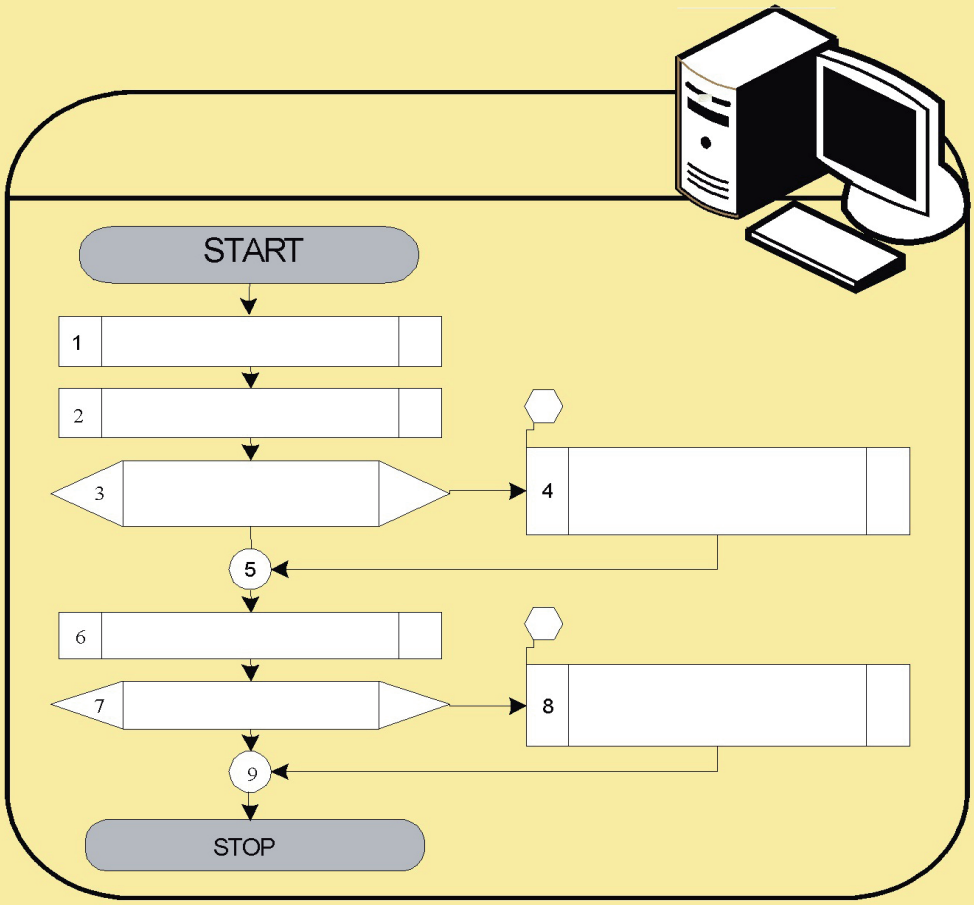
APPLIED COMPUTER SCIENCE

Vol.9, No.2, 2013



LUBLIN UNIVERSITY OF TECHNOLOGY

INSTITUTE OF TECHNOLOGICAL SYSTEMS OF INFORMATION

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ISSN 1895-3735

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Editorial Office:	„Applied Computer Science" Editorial Office 20-618 Lublin, ul. Nadbystrzycka 36, Poland Tel.: (+48 81) 538 44 83 Fax.: (+48 81) 538 46 81 e-mail: acs@pollub.pl www.acs.pollub.pl
Circulation:	550 copies

APPLIED COMPUTER SCIENCE

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The Journal is published twice a year and is indexed in BazTech. Publication in Applied Computer Science is free of charge.
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CONTENTS

Przemysław Plecka[*]*, Krzysztof Bzdyra*[**]

ALGORITHM OF SELECTING COST ESTIMATION METHODS FOR ERP SOFTWARE IMPLEMENTATION

Abstract

The article discusses the problem of selecting estimation methods for cost and implementation time for ERP systems, in case when system modifications are necessary. The authors reviewed the methods available in the literature and characterised the stages of strategic phase in the implementation process. On the basis of the analysis of data range and quality required by each method and the data obtained at different stages, a selection algorithm for each stage was proposed.

1. INTRODUCTION

At the moment all significant software producers have their standard product in ERP-class: SAP – Business Suite, Microsoft – Dynamix AX, JD Edwards – EntrepriseOne, etc. During trade talks while the systems the parties reach a conclusion that the organisation of processes in the company does not fully overlap with processes supported by the computer system that is available [1]. There is a group of processes that is not represented in any functionality in standard ERP system. This generates a need for adapting information systems (IS) to a company. The costs of modifications increase the value of the contract (implementation). In some cases it is the company that adapts processes to the system, however, the costs of organisation changes are an additional burden to the client. It is only when clients recognise the costs of system implementation (including adaptations), they incline to consider changes in their organisations. In order to give supplies the basis for negotiations, cost estimation at very early stages of implementation is crucial.

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While estimating the costs of modifications, software providers encounter difficulties in selecting appropriate method. Usually, they select one that they know best and use it throughout the estimation process. Such an approach causes large estimation errors [2]. A tool suggesting the method that produces the most reliable results would be helpful for software developers. After each stage of selling process, the supplier might verify the data that was gathered and obtain a suggestion which method to choose. The stages of software lifecycle [3] and software valuation methods are known. The question is which of the evaluation methods produces most appropriate results of costs and time at a given stage of strategic phase of IS implementation. The scope of the problem was limited to ERP class information systems implemented in medium-sized enterprises.

The methods facilitating valuation of software production are known and discussed in literature, e.g. by McConell [4]. However, due to changes in information technologies, the popularity of their use has still been changing. The use of algorithmic methods at initial stages of information projects is difficult. At that stage there are no analytic or project documentations, whose components facilitate estimating algorithms. Despite the fact that the uses of algorithmic methods at early stages of information projects can be found in literature [5, 6], the practice of information project suppliers indicates a common use of non-algorithmic methods as faster (i.e. cheaper) and easier. In literature, one can find suggestions for using cost evaluation methods for information projects, starting with statements that any combinations of methods should be used, through views about when and what methods should be used, and finishing with "step by step" procedures [7].

Negotiations with ERP system suppliers and clients concern two elements: costs and implementation time. Consultants estimating the cost of software use such time-consumption measures as man-hour, man-day or man-month. With a given cost of a working unit of time for implementation, it is possible to calculate the cost in a given currency and the time (dates) of implementation, with consideration for possible simultaneousness of certain works.

Chapter 1 of the present article includes the description of stages in strategic phase of implementation project with consideration for the quality of data available for valuation. Another chapter is a review of algorithmic valuation methods. Chapter 3 includes the description of non-algorithmic methods. The final chapter presents the conclusions resulting from the connection of effects from lifecycle stage and the data necessary for software valuation. On this basis an algorithm using a selection questionnaire to choose an evaluation method at each stage of strategic phase.

The use of symbols in Fig. 1, 3, 4, 5 and 6 is in accordance with BPMN 2.0 [8], even if full schemes may not be coherent with the notation.

2. LIFECYCLES STAGES OF ERP SYSTEM IMPLEMENTATION

Numerous authors describe software lifecycles focusing on software production or developing software on individual client's order [3]. None of the presented models corresponds entirely to implementation process of ERP-class software in a middle-sized company. They do not consider "flexibility" of the end of strategic phase (concluding a contract) and possibilities of having one additional stage – feasibility study. Feasibility study is not significant for software lifecycle, however, it provides information for project valuation. The stages of strategic phase are the following:

1. Initial trade talks.
2. Pre-implementation phase.
2' Feasibility study.
3. Project of changes in the system.

The stages of strategic phase and other phases of software lifecycle (implementation, integration, evolution) are presented in Figure 1.

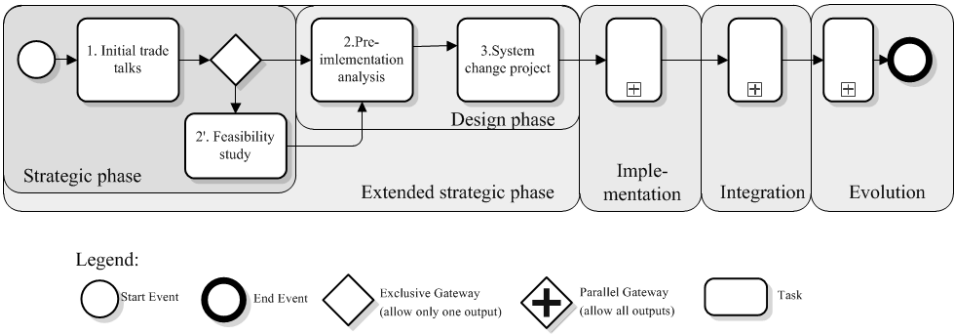

Fig. 1. The stages of strategic phase and other phases of ERP system [source: own study]

Considering cost evaluation, one should remember that in the sales process the moment of contract conclusion is significant. It may happen right after stage 1 but not later than after the end of stage 3. The period is called the strategic phase. It is in IS supplier's interest to get the contract signed as soon as possible, as the implementation of subsequent stages increases the costs with the risk of failure to conclude the agreement at all. However, early estimation of costs involves higher risk of estimation error.

2.1. Initial trade talks

The supplier has meetings with a prospective client in order to define the scale and value of the contract. Usually it is one initial meeting followed by two or three presentation meetings. Some of the elements of work range are identified

quickly and precisely. The concern primarily computer hardware, network infrastructure and licences for individual ERP modules. Some elements, e.g. IS modifications that result from non-typical users requirements are difficult to define. At this sate the supplier cannot fully identify the needs that are not satisfied by the standard version of ERP system. As clients' knowledge on IS comes from trade presentations, they cannot define precisely which requirements are not standard. The requirements that supplier is able to obtain from the client are usually incomplete (requirements that the client considered unimportant are missing) and general (client is not able to define the level of specificity).

If the supplier can specify client's expressed requirements and suggest the un-expressed ones, attempts can be made to evaluate the changes. For example, a client defined the requirement in production area concerning separate order for materials from A group of goods for each commission. Such a requirement suggest un-expressed requirement of ordering in the area of logistics, where the management of goods from group A must be excluded from the general plan of orders. Both requirements should be evaluated, even though only one of them was specified by the client. At this stage, single, specified requirements are expressed: reports aggregating the same data in different forms, printout in a specific form used by the client,

2.2. Feasibility study and pre-implementation analysis

If the supplier was unable to evaluate system adaptation (modifications) works clarification and specification of client's needs must be done. Then a pre-implementation analysis or feasibility study is prepared [9]. Although both solutions are aimed at specifying the data for the evaluation, the basic purpose of each is different.

Feasibility study includes information on the company in a form of a systematic document based on economic facts [10]. The information concerns economic, organisational and technical aspects. The aim of the study is to define the range of works and the costs of the project. The document is used by supplier's decision-makers while analysing economic aspects of project implementation.

Pre-implementation analysis does not include other the information than this concerning computer system in the context of a given company and the work. The result is a report including the following components: functional range of the implementation, list and description of business processes, functions and data advised to be included in the functional range of the system, organisational range of the implementation, the proposed aims of the implementation, expected business benefits, schedule of work [11]. At this stage the supplier assumes that the requirements are complete and their level of specificity meet developers' expectations, who rely on this document in their further works.

Even in a medium-sized production company recording all user requirements and processes would be very time-consuming and expensive (from a few thousand up to over a thousand requirement). Moreover, in most cases they would overlap with the records in ERP system documentation. Therefore, suppliers make a differential analysis which includes only those elements that are not covered in a standard IS. Such a procedure shortens the time of stage implementation but also allows the client to see the documentation of a standard version with the pre-implementation analysis.

The supplier should evaluate the quality of requirements that were expressed at this stage for the use of software evaluation method.

2.3. Project of system changes

Project of information system is an intermediate phase between defining the requirements and the implementation. The documentation the is produced exclusively for internal use of the supplier (software departments). Depending of methods of implementation (structured, object-oriented programming, or agile software development, etc), project documents may include different elements [3]. Some ERP system developers worked out their own specific methodologies. In such cases the documentation will be specific. One such example is Select Perspective methodology [12, 13] or ARIS [14]. However, there are always common elements for evaluating software.

The first element of software developing is to specify the requirements resulting from implementation character. The level of requirement specificity must determine the manner of implementation in an unambiguous way. Despite this, project documents include the elements describing data structures and procedures of processes. There is a number of methods for presenting project information: from DFD [15], Entity-Relationship Diagrams, through UML models [16]. Each of them is an appropriate source of date for software evaluation.

2.4. Summary of lifecycle stages

With subsequent stages of software lifecycle supplier's knowledge on the differences between processes in the company and standard software functionalities grows. At first they have only one, incomplete set of general requirements. In subsequent stages requirements are completed and specified. After the project stage, the supplier can additionally use project elements such as: data objects (tables, fields), windows, interfaces, etc for evaluation. On the other hand, supplier's costs grow. If a contract with client is concluded, the costs will be included in the contract value, if not, they will be the supplier's cost. Input information necessary for making valuation at the subsequent stages of project lifecycle is presented in Figure 2.

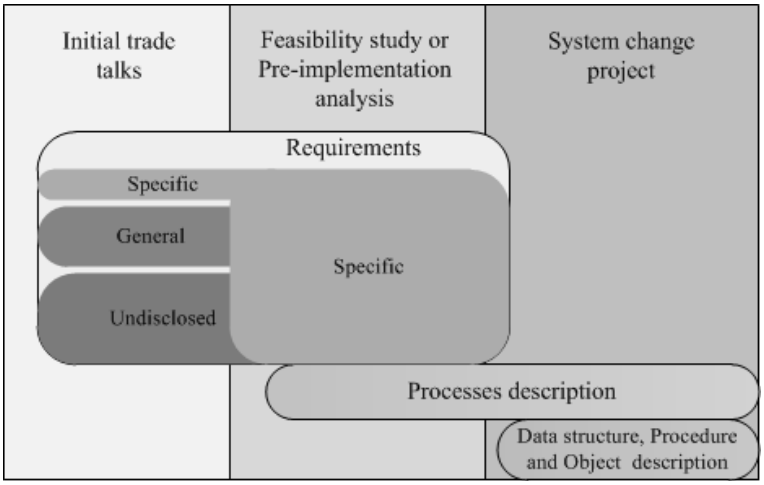

Fig. 2. Input information for evaluation process [source: own study]

3. ALGORITHMIC METHODS OF SOFTWARE EVALUATION

3.1. COCOMO II method

Constructive Cost Model (COCOMO) Method was proposed by Barry Bohem in 1981 [15]. Since then a number of versions and types of this method have been developed, e.g. COCOMO81, COCOMO II [16]. The sequence of processes comprising the evaluation is presented in Figure 3. With the use of COCOMO method Person per Month (PM) can be calculated on the basis of the amount of source code in the programme Kilo Source Line of Code (KSLOC) (process 1 in Figure 3). The information necessary for evaluating the amount of code are obtained from the IS project documentation. The amount of KSLOC are attributed to a number of programme elements, such as procedures, modules, objects, etc. Because for many contemporary uses the amount of code does not correspond to PM, the method was modified by using function point analysis [17] (process 2 in Figure 3) calculated on the basis of compete and specific requirements. The analysis of function points was presented in the next chapter.

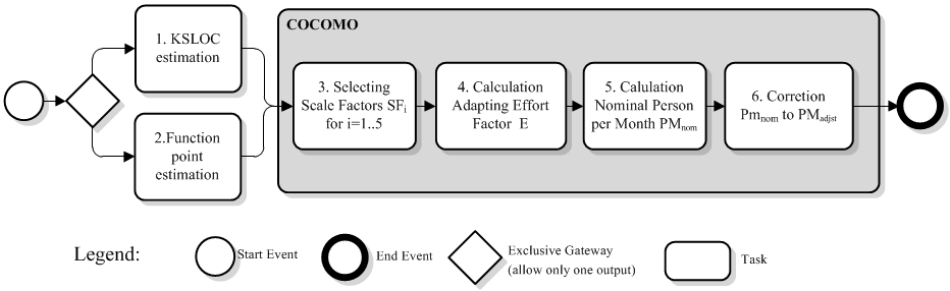

Fig. 3. Sequence of processes in COCOMO method [source: own study]

The first activity is defining five Scale Factors (SF), whose value was determined empirically in five classes, depending on the level of complexity (from very low to very high). Knowing the value of individual factors, the factor adapting effort (E) can be determined from the formula (1):

$$E = B + 0{,}01 \cdot \sum_{i=1}^{5} SF_i \tag{1}$$

where:

B – constant 0.91 for COCOMO II model [23].

Nominal Person per Month PM_{nom} is done in accordance with the formula (2):

$$PM_{nom} = A \cdot (Size)^E \tag{2}$$

where:

Size – the number of code lines In KSLOC unit,

A – constant determined on the basis of previous projects = 2.94 [23].

For models from the first stages of Application Composition Model, Early Design Model [17] nominal time should be corrected with seven coefficients of Person per Month, in accordance with the formula (3).

$$PM_{adjs} = PM_{nom} \cdot \prod_{i=1}^{7} EM_i \tag{3}$$

where:

EM_i - Effort Multiplier.

For the models in another lifecycle stage (Post-Architecture Model) the formula for nominal Person per Month was enriched by 9 indicators (i=1..16). Alike *SF* values, *EM* were determined empirically. The data for SF and EM calculations can be found in method documentation [17].

The literature includes a number of examples of adapting COCOMO method [18, 19] with the use of fuzzy logic, inter alia [20, 21, 22].

3.2. Evaluation with the use of function points

Evaluation method proposed by A.J. Albrecht [23] requires the calculation of the number of function points (FP) on the basis of specific requirements. Then COCOMO method or *Evaluation by Analogy* can be used to calculate the number of FP into Person per Month or costs. The set of user requirements that is used in calculations must be complete and all the requirements must be specific. The process of evaluation with the use of function points is presented in Figure 4.

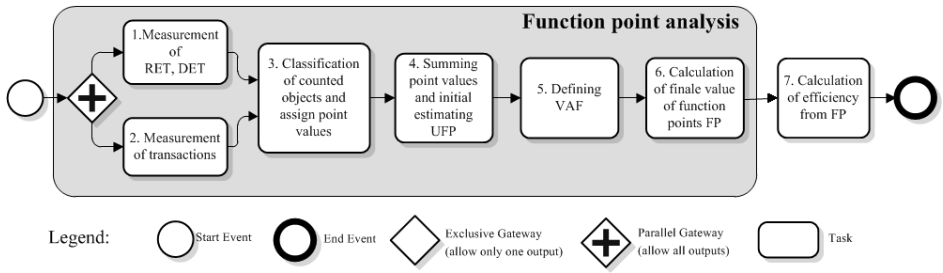

Fig. 4. Evaluation process with the use of function points [source: own study]

Function points method is based on selecting five classes of objects in requirements or the ready program (processes 1 and 2 in Figure 4):

1) Internal Logic File (ILF),
2) External Interface File (EIF),
3) External Inputs (EI),
4) External Outputs (EO),
5) External Inquires (EQ).

The first two classes are related to data, the three other – transactions. To make estimations at this first stage, the following indicators are used (process 3 in Figure 4):

- RET (Record Element Type) - unique, recognisable subgroup of elements given in ILF or EIF, correspond to the record in the table;
- DET (Data Element Type) - Unique, identifiable field in ILF or EIF, correspond to the field in record;

- FTR (File Type Referenced) - recognisable by users, logically related data, correspond to files or relationally connected files.

All objects in classes must be identified and attributed with appropriate value of indicators ILF and EIF are described with RET and DET, while EO, EI and EQ with FTR and DET. In this way the number of Unadjustment Function Points for a given objects is read from the table. Summing *UFP* values of all objects in all classes the total value of Unadjustment Function Points is obtained.

Value Adjustment Factor – VAF considers for internal system complexity, unrelated to its functionality. Defining the value entails giving the impact of 14 factors, which may raise system complexity (process 5 in Figure 4). The list of factors can be found in method documentation [24]. VAF value is calculated from the formula (4):

$$VAF = B + 0{,}01 \sum_{i=0}^{14} C_i \tag{4}$$

where:

B – empirically determined constant value 0.65 [31],

C_i - impact value of i-th factor.

On the basis of VAF the final values of function points are calculated by correcting the Unadjustment Function Points according to the formula (5):

$$FP = VAF \cdot UFP \tag{5}$$

Knowing FP value, efficiency can be determined with two methods (process 7 in Figure 4):

- calculating into KSLOC with empirically determined values from calculation table [25] and then use COCOMO method to define Person per Month,
- If the organisation owns historic data, FP value can be directly calculated into Person per Month, using Estimation by Analogy method.

The source of compete and updated documentation of the method is website of International Function Point Users Group [26].

4. NON-ALGORITHMIC METHODS OF SOFTWARE EVALUATION

4.1. Decomposition and reconstruction

Decomposition and reconstruction is a popular method due to its intuitiveness and universality. It is used in situations when whole project evaluation generates difficulties, e.g. resulting from work heterogeneity. In practice of IT project implementation [29] there are very few project that can be evaluated without this method.

The method involves decomposing the range into a number of components. The method of division is arbitrary and depends on project specifics. Suppliers frequently do evaluation with Work Breakdown Structure (WBS) method [13]. Having done the division, the parts of objects are estimated and undergo further division with the same or other method. The "depth" of division depends on the evaluation methods that is going to be employed in the next stage. Even though the literature lists this method as equal to others [4] its role in the evaluation process is different from others. Project evaluation is started in this method, but after decomposition, other methods of elemental evaluation are selected. A detailed description of decomposition method according to WBS can be found in literature [27, 28, 29, 30].

4.2. Individual expert evaluation

The method of valuation by *individual expert evaluation* is the most frequently used method, not only in software development [31], but also in other IT enterprises such as implementations and modifications. The research conducted in USA in 2002 showed that as many as 72% of the valuations are done with this method [36]. In the first stage, the method requires selecting experts with appropriate knowledge and experience. Then experts evaluate the ranges they were bestowed. In order to reduce the evaluation errors, the method was modified with multiple evaluation for different versions of implementation. Such a technique, called PERT (Program Evaluation and Review) [27, 33], involves analyses of the most optimistic, the most probable case and the worst case. However, it is different from critical path analysis (CPM [34]) because it is used to evaluate independent tasks only. After previous decomposition processes, the information about relations between tasks was lost. The expected evaluation has the following form, then:

$$f(x) = \sum_{i=1}^{N} (Cp(x_i) + 4 \cdot Co(x_i) + Ck(x_i))/6 \tag{6}$$

where:

C_p – the most optimist value of the i-th task,
C_o – the most likely value of i-th task,
C_k – the most probable value of i-th task.

The specificity of results in this group depends entirely on expert's experience. Selection criteria are imprecisely defined. The influence of personality is significant in as much as experience does not guarantee more precise evaluations. There are undervaluing, overvaluing or unexpected experts.

The method can be used from supplier's first contacts with the client. With appropriate use of experts, evaluation can be done even on the basis of incomplete set of general user's requirements.

4.3. Group expert evaluation

The method involves presenting the same range of work to more than one expert. In unstructured version of the method (group review) the experts decide about the valuation or its range as a group. In a structured version, called Wideband Delphi [35, 15], experts' work is done in a formalised way and its result is a scoring evaluation.

The work of experts in groups is more expensive than individual work, however, method' advantage over *individual expert evaluation* is the decrease of personality factors' importance. In spite of different experience, characters and inclinations, experts will either reach a common ground or, as in case of Widebrand Delphi type, the conclusion of problem is reach by attributing pre-selected points.

Estimation method is used frequently at initial stages of IT projects in situations of high uncertainty of requirements.

4.4. Summing, computing, evaluating

The method concerns searching quantifiable objects, e.g. requirements, functions, use cases, stories, reports, windows, database tables, classes in the project. Each identified object that can be summed is attributed with estimation constituent (cost or time). The estimated values are the function (7) of the objects constituting an information project:

$$f(x) = \sum_{i=1}^{N} C(x_i) \tag{7}$$

where:

x – calculated object,
N – the number of summed objects,
C – computer cost of the object.

The method can be used at every stage of software development or modification. The method is not complex provided the source documentation allows determining the summed objects. One of the failures is high risk of omitting objects or ranges of work that influenced the value of the whole project, for example, ignoring supplementary tables or costs of developing filtering inquiries while evaluating the costs of interface windows. Important stage in this method is the evaluation of individual objects' costs. The stage of individual object evaluation is an important stage of this method. This can be done with help of *Individual expert evaluation* or *Group expert evaluation*. The method is efficient in projects with a small number of object types are identified but they are plentiful, e.g. 30 reports, 25 SQL inquiries and 18 interfaces.

4.5. Evaluation by analogy

The method concerns dividing the project into components that already exist in a completed project. Evaluating selected parts, one may calculate the ratio of two projects' sizes (new and the completed one). Knowing the relations between the sizes and the costs of the completed project, one may estimate the value of the new project.

The difficulty lies in collecting historic data from similar projects and structure as the evaluated project. Additional problem is the selection of a representative part of the decomposed project, which is a basis for multiplicity factor. Ignoring significant objects may increase the evaluation error.

The input data for this method comes from data objects and programmes (interfaces, SQL queries, FP). The use of requirements, even the specific ones, does not allow calculating multiplication factor, thus doing the whole evaluation. Therefore, the method can be used when the effects of programming are known.

4.6. Valuation based on substitution

Alike the previous one, this method requires the knowledge of costs of previously completed in organisation of standard objects (interfaces, reports, etc). Depending on the version of method, the objects can be grouped differently. For example, Putnam [33] and Humphrey [36] selected classes of objects: very small, small, medium, large and very large. Another method of classifying the objects is a standard component method [4] used to valuate object software. If the IS system supplier uses extreme software or close to Agile methods [37], so called "stories" might be a standard element.

Then, the groups of objects are attributed with average cost values, e.g. number of lines of code (LOC), man hours or man days. The objects from a new project must be classified in the same manner. Then their sum can be calculated. Similarly to the previous method, this one should also be used when classes of programming objects are known. One exception is the organisations using extreme or agile programming. In this case, the costs of "stories" that were documented at the stage of talks to clients can be substituted with historic data. The practice of evaluations [2] implies that it can be used at earlier stage (preimplementation analysis), when only specific requirements are known.

4. CONCLUSIONS

Concluding, one should notice that implementation of the first stages of software lifecycle provides more and more information about the planned solution, on the one hand, and there is a number of evaluation methods available on the other hand.

On the basis of the analysis of evaluation methods, the authors propose their own method of selecting precise method of evaluating implementation cost and time (modification of software during implementation).

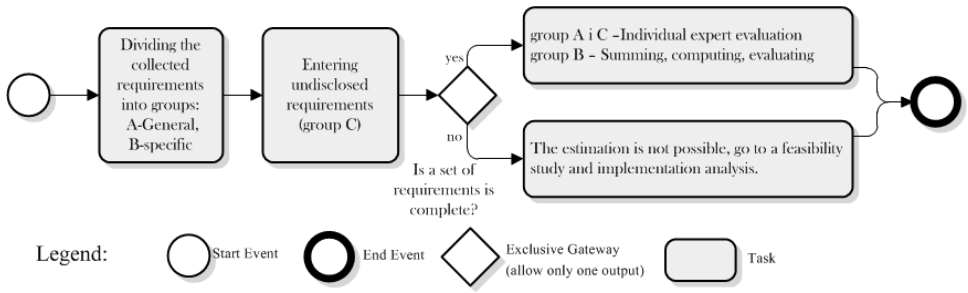

Fig. 5. The method of evaluation at the stage of trade talks [source: own study]

For the trade talks, the algorithms of conduct is presented in Figure 5. As it is presented, for all the groups of requirements time and cost can be estimated only in cases when the set of requirements is complete. As software developers do not mange to complete the set of requirements with a subset of requirements unexpressed at the stage of feasibility study or implementation analysis. In such a case other evaluation methods are available, what is presented in Figure 6.

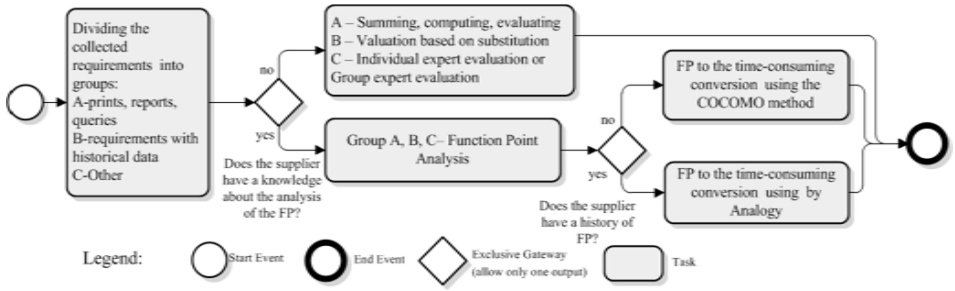

Fig. 6. The selection of evaluation methods at the stage of implementation analysis (feasibility study) [source: own study]

The stage of system change provides, along with additional requirements, the information on the works – data structure, information on the procedures, objects, etc. Alike in previous stages, the supplier should classify the available data. The algorithm of actions is presented in Figure 7.

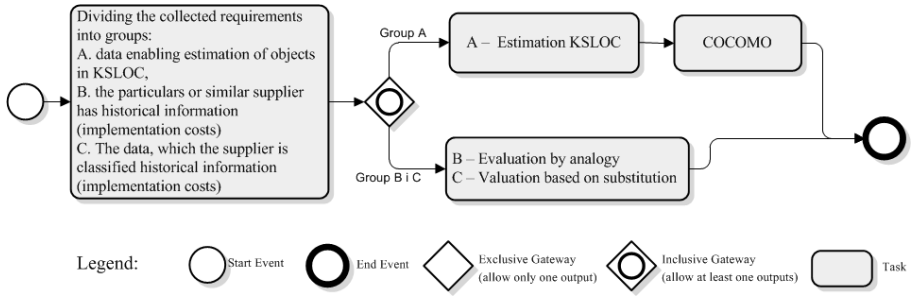

Fig. 7. The selection of evaluation methods at the stage of software project [source: own study].

The above proposition allows using the methods which are most efficient at each stage.

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EDI electronic documentation, mass customization, product family, industrial engineering

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DISTRIBUTION OF INFORMATION AND DOCUMENTATION FOR THE MANUFACTURING PROCESSES OF THE HIGH-VARIETY PRODUCTS – CASE STUDY

Abstract

In the last years the researches in engineering have moved towards customer-oriented manufacturing. The individual customer's requirements are very important for the company's activities. It results high-variety production. High-variety production like mass customization is facing the challenge of effective variety management. Applying methods of mass customization to the empirical process can improve product development process efficiency and reduce time and cost. The manufacturing process requires documentation of the production. Very often, the documentation process and the time of its formation is limited. The article includes an analysis of the modern manufacturing systems and answering the question: how is it possible to produce without having a documentation in paper form. The presented solution is used during the high-variety products manufactured in the SMEs. The method was validated in the conditions of best practice high-variety production.

1. INTRODUCTION

In the past the fundamental objectives for most companies were to produce as cheaply and efficiently as possible and to reach as large a customer group as possible with the same product (mass production philosophy). The customer orientation is one of the most essential strategies for every manufacturer.

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Previously the primary source of competitive advantage for manufacturing companies in many industries was related to price. Therefore, all manufacturing strategies were driven by attempts to reduce the cost of the product. Technological advances, in manufacturing as well as in information, have provided the impetus for change in many paradigms, including customer expectations. Customers have become more demanding and want products that can meet their specific individual requirements. Producing customized products at a low cost, which seemingly is a paradox, is the purpose of many enterprises. This main purpose, which is considered as fulfilling customer needs, results in production by unit and small batch process [2, 19].

For many companies, this implies a need of production, in short cycles while keeping a cost criterion. Reducing the time from the moment of customer decision to receiving product may involve many aspects: a presentation of an attractive offer, the acquisition order, the process of product data preparation and issue of manufacturing documentation, the manufacturing process and delivery of the product to the customer. In this article the author focused on the issues of product data preparation, documentation of the manufacturing process and its distribution. Currently, a very important issue is supervising changes in manufacturing processes and thus the emitted documentation. Printed documentation has the disadvantage. The change can be made when user finds documentation and all the copies.

Currently many companies use IT systems supporting the organization of the manufacturing process. However, to what extent the SME's can use existing IT systems to manage the manufacturing process using only documentation in the paperless form? This is a question that the author of this article want to answer.

The paper is structured as follows. First, the studied problem is shortly described. Then, an example to illustrate the problem is presented. The main part of the article consists of an analysis of variants of data collection, preparation of high-variety product data and manufacturing management using paperless forms of documentation. The article concludes with some summary remarks.

2. PROBLEM BACKGROUND

2.1. Product variety management

Past research on product variety management explored multiple solutions to overcome varies difficulties. Some scholars focused on integrated approach for flexible manufacturing systems [12] others on product structure and specification [6, 1], mass customization, part family manufacturing and group technology (GT). The concept of Mass Customization (MC) has received considerable attention in the research literature [3, 7, 23, 24, 27, 9, 15].

In the MC environment, customers are placing unprecedented pressure on manufacturers to deliver a highly customized product at a highly accelerated speed and at highly reduced cost. The companies are finding it extremely difficult to manage these conflicting priorities and they are looking for innovative ways to optimize their systems so that they can satisfy the demanding customer of today [12]. The fundamental modes of operation for mass customization were given in many publication among others [11, 26, 25].

The changing economy world has caused an increase in the use of just-in-time manufacturing, which results in a trend toward short-run, multiple-product manufacturing. The frequent product changeovers make it imperative to improve setup operations and shorten line changeover times.

2.2. Trends from a paper-based to a paperless factory

Paperless factory is not the main goal of companies. The goal is a response to the customer needs by improving quality and on-time deliveries, shrinking manufacturing cycle time, and minimizing waste. Over time a variety of technologies led to the development of an infrastructure that enabled the paperless factory. In [5] author presented a review of issues and technologies used currently in the paperless factory. Yao [8] and Porter [22] emphasized the effects of "wireless connectors" in manufacturing workstations to improve inventory control and the timeliness of real-time data. Li, et al. [10] described the application of some computer web-based technologies, such as visualization techniques, to establish a integration of product design with paperless concurrent engineering design.

Traditionally, data communication among various functional areas of a factory (Figure 1) has been made by the exchange of blueprints, routing sheets, inventory lists, shop floor travelers and so forth. Often papers occupied too much space and cost too much to process. Doing business on paper slowed the pace of the enterprise to the speed at which paper traveled in the factory. To improve their systems, some companies required that their operations function without paper. They used workflow automation to define paths for electronic documents to travel automatically [5, 20].

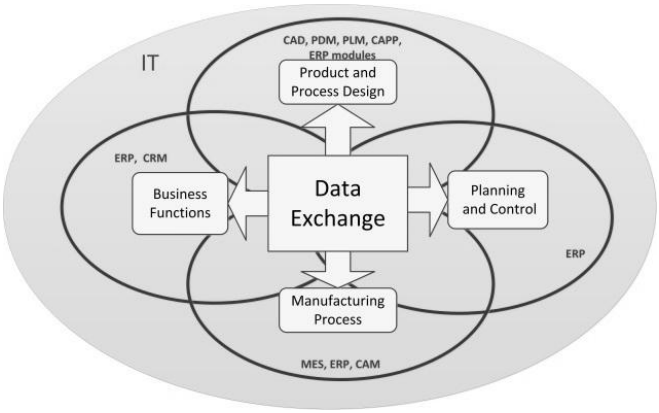

Fig. 1. Data Communication with IT systems [20]

Today, also in SMEs, to solve the problem of data exchange IT are used (Fig. 1). The dominant role in business activities play an ERP and CRM systems, in product and process CAx, PDM, PLM, CAPP and ERP modules, in planning and control ERP and in manufacturing process area MES, ERP and CAM systems [2, 13]. Largely in SMEs the heterogeneous solutions are used.

2.3. Model of high-variety products

A model of high-variety products is based on an analysis of the product's feature. The model is an abstraction of the real world product family that is specifically meant for configuration purposes. First thing to do is to specify attributes for the products, like colour, size, kind of drive, etc.

In this case solution on the basis AND/OR graph representation was implemented [14, 28]. 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 $P = \{P_1, P_2, .., P_n\}$ with AND relation. Each solution $P_i | \forall i \epsilon [1, N]$ could be derived through configuring the configurable modules, $M = \{M_1, M_2, .., M_n\}$.

Each configurable module $M_i | \forall i \epsilon [1, K]$ may possess several available module instances $M_k^* = \{CA_{k1}, CA_{k2}, \dots, CA_{kL}\}$ 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 $= \{a_{kq}\}$, 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.

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 $C_j \neq p_{j1}$.

3. PROBLEM FORMULATION

The problem discussed in this paper concerns the paperless manufacturing of high-variety products. To solve this problem the point is to find an answers to the following questions:

- What data for configurable high-variety 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?
- How to manage the distribution of information and paperless documentation of manufacturing process?

To illustrate the above problem a simple example is given.

4. ILLUSTRATIVE EXAMPLE

4.1. Product family

The example in this paper is the customization and production of product families for roller shutters manufactured in SME. Roller shutters are one example of family products.

The shutter can be made in many options. Product elements are given in Fig. 2. The main optional features are: system profile, dimensions: height and width of the blinds, color, drive type and others [21].

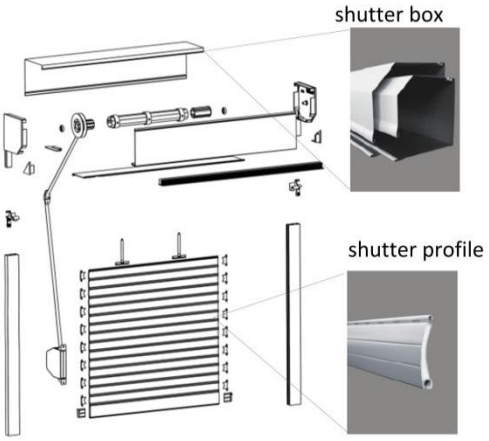

Fig. 2. Roller shutter's components [21]

4.2. Characteristics of the production process

A crucial role in waste-free manufacturing of roller shutters is played by the rollforming line. The production of the high-variety product (product family) (see Fig. 2) assumes zero waste of roller shutters. A crucial role in waste-free manufacturing of roller shutters is played by the rollforming line. It's possible to produce, in one process, a complete roller shutter curtain. The rollforming line is equipped with tooling suitable to produce the foamed roller shutter profiles in different sizes.

The process consists of foaming, punching and cutting to length operations. The line is designed for high density or low density foamed profiles. It is also possible to add a stacking bench to make packages or to cut to length curtains complete with side caps. Depending on the type of profile the line can reach a productivity of approximately 50-60 m/min. Unfortunately, the changeover time of the line is 2 hours. Until now, shutter manufacturing was based on profiles supplied in 6m sections. The profile was then cut to length according to individual customer requirements. The next stages of the process were the curtain assembly, the box cutting and the final assembly of other materials and components. Manufacturing from 6 m profile sections did not allow for waste-free production. It's possible only on the rollforming line with cutting to length according to individual customer requirements. The above line is computerized numerical controlled (CNC) and the controlling data are transmitted automatically by the manufacturing execution system (MES). The process can be implemented by alternative routes [16, 17].

5. SOLUTION METHOD

Below are presented the possible scenarios of solution with special reference to the high-variety production.

5.1. Business area

In the business area possibility of paperless documentation is largely determined by the law. Introduced in recent years, changes in the law have allowed the wider use of electronic signatures and electronic invoices. The data exchange between business partners is via e-mail or web portals. In the case of optional products a key role plays product configurator. 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.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE supplier_order SYSTEM "bestellung_anwis.dtd">
<supplier_order>
  - <supllier_data>
        <order_date>2012-06-20:15.15</order_date>
      - <recipient>
            <![CDATA[AN A.G. ul. Wilcza 16/18 43-900 Bielso, Polen VAT No.
            PL8882896226]]>
        </recipient>
    </supllier_data>
  - <orders>
      - <plissee>
          - <order>
              - <customer_data>
                    <commission>P-389082- [JD895555]</commission>
                    <prename>Ralf</prename>
                    <lastname>Buck</lastname>
                    <ordernr>384282</ordernr>
                </customer_data>
              - <konfiguration>
                    <width>740</width>
                    <length>1130</length>
                    <quantity>1</quantity>
                    <stoff>BC_18</stoff>
                    <stoffseite>R</stoffseite>
                    <bedienung>R</bedienung>
                    <halterart>B</halterart>
                  - <profilfarbe>
                        <![CDATA[silber / grau]]>
                    </profilfarbe>
                    <system>VS2</system>
                    <neigungswinkel>ohne</neigungswinkel>
                  - <bemerkungen>
                        <![CDATA[Klemmtraeger]]>
                    </bemerkungen>
                </konfiguration>
                <dispatcher>DHL</dispatcher>
            </order>
```

Fig. 3. Order with configuration (XML file) [source: own study]

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.

The main problem is constituted into the interface for submitting orders. The interface must be clear, transparent, dynamic, graphical and in correlation to changeable requirements.

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. 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.

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 [16, 17].

Electronic order example is shown in Fig. 3. In extension to the standard information for high-variety product the configuration options are required.

5.2. Product & Process design

Building the knowledge base for configurator is a real challenge. Not all companies 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.

A configuration problem (CP) is formulated as [14]:

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

where: C – set of options that may constitute a customizable product,
P – set of properties of options,
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.

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

$$Ce : \{CP\} \rightarrow \{a\ finite\ set\ of\ CS\} \tag{4}$$

Due to the number of possible options for process planning the generation process planning method is used. In this case DPE modules are prepared.

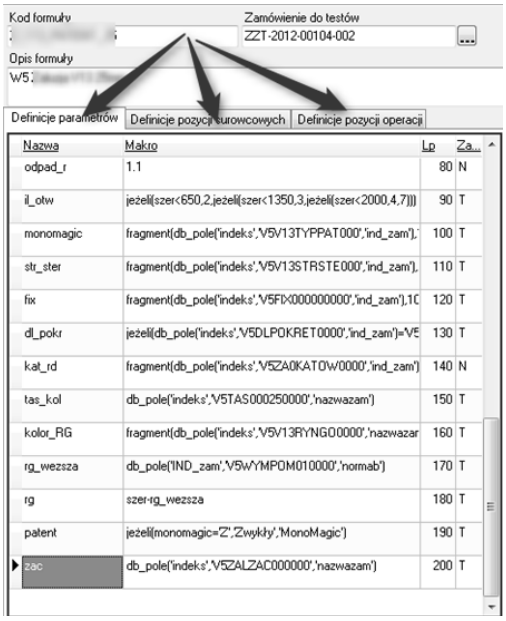

Fig. 4. Parameters definition for BOM and process routes [source: own study]

A data preparation engine (DPE) is a module that maps a configuration engine (Ce) to sets of BOM (Bill of Material) 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 process (DPE_{RPP}) [14].

$$\mathrm{DPE}_{\mathrm{BOM}} : \{Ce\} \rightarrow \{a\ finite\ set\ of\ BOM\} \tag{5}$$

$$\mathrm{DPE}_{\mathrm{RPP}} : \{Ce\} \rightarrow \{a\ finite\ set\ of\ RPP\} \tag{6}$$

In practice, it comes down to define a set of formulas assigned to the product family. Every formula is composed of three elements: a set of parameters which values are mostly map of configuration parameters (Fig. 4), a definition of raw material or assembly unit, and definition of routing process.

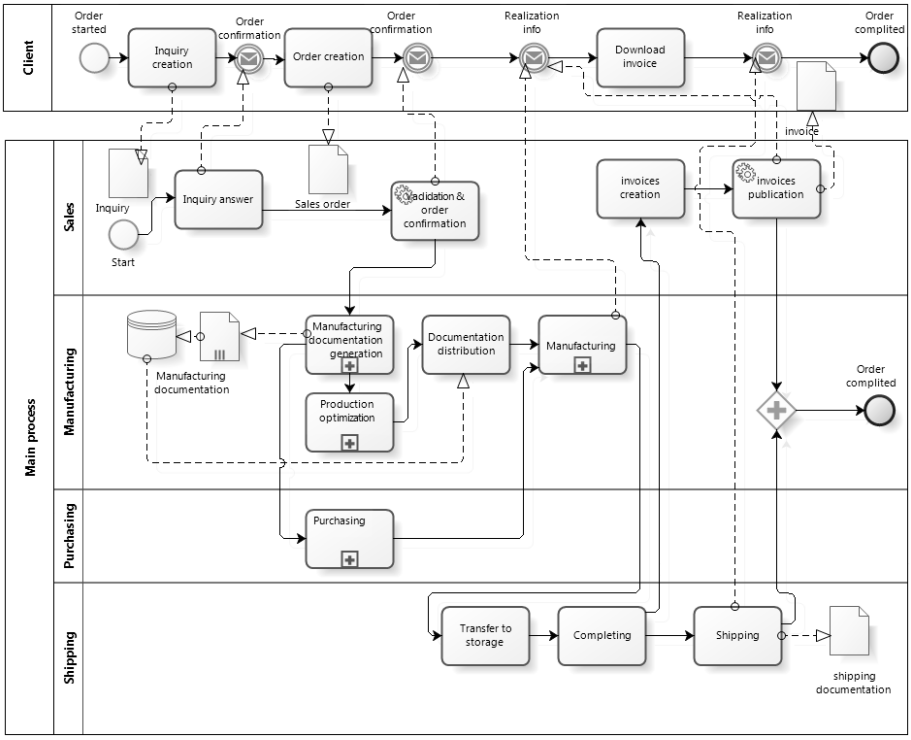

Fig. 5. Process flow in small and batch production [source: own study]

Planning and control take place according to the process shown in Fig. 5. One of the important problems to solve is the distribution of documentation. It is closely connected with the its functions: identification of the product, definition manufacturing routes and function of a carrier for data collection. Implementations of these functions must take the operator panels.

Unfortunately the disadvantage of this solution is the relatively high cost associated with the creation of a full network infrastructure for every workstation (operator panels, WiFi network). To reduce costs the hybrid solutions are implemented (Fig. 6). The hybrid solution is a compromise between the costs and the benefits from the work "on line". Operator panels are installed only on the selected workstations. The criterion for selection is rather simple and it is associated with "bottlenecks" of the manufacturing process. Workstations which are bottlenecks are monitored and special controlled.

If the above workstation are ready to communicate with the machine via MES tools the solution is more cost-effective. Management system such as ERP gives the information about the job orders, gives the processing parameters (eg. CNC program number) and gets back information about performance. The process of data acquisition does not require human intervention and thus is much more reliable.

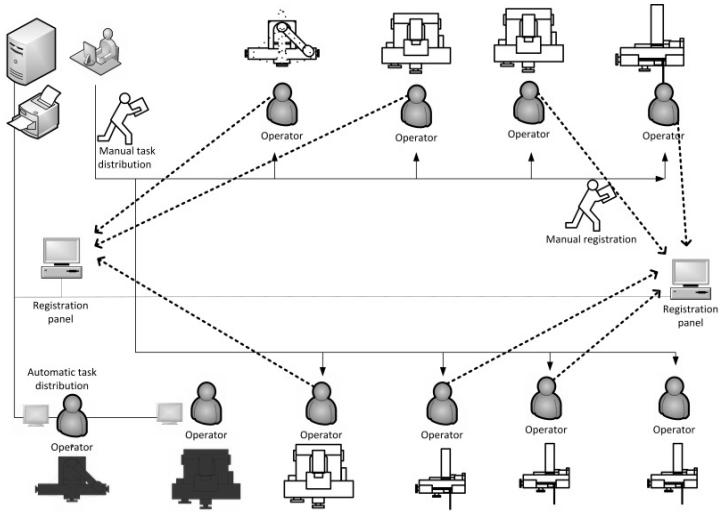

Fig. 6. Paperless workshop [20]

The next generation of factories could be a part of digital enterprises that collaborate around the world with their systems and business processes. In digital factory manufacturing could be more agile, responsive, productive, profitable, and humane than manufacturing in contemporaries enterprises is today. In an integrated systems, processes, manufacturing, and management personnel work collaboratively to prepare and release information to the factory floor. Simultaneously, factory workshop operators have simplified access to dynamic documentation that helps them do their job effectively.

6. CONCLUSIONS

The contemporary customer requirements, determine the production systems.

Today, paper form of documentation has not been eliminated. But, paper substitutes or representations require improving management processes in the factories. Operators panels provide the shop floor with operational status, and production control data such as work-in-progress and quality control charts.

The trend to change from a paper-based to a paperless factory has gained momentum over time. It was enabled by the application of the existing technology of wireless communication on the factory floor and the introduction of new technologies and concepts such as RFID and web systems.

However, implementing a true paperless factory is a challenge. In the case of configurable products it requires knowledge base preparation. It requires also improvement in data security, integrity and evolution of existing technologies.

Eliminating redundant documentation can, in many cases, significantly improve the organization of the production process. It can not be a goal in itself. The resignation of the documents in paper form improves the quality of management. In a high-variety production the management of change is very important, both in the process of the preparation of documentation and its distribution on the manufacturing workshop. Analysis of documentation emitted inside individual processes (business process, data preparation or production scheduling or control), show that there are fewer places where it is emitted unnecessary. The situation is worse if we look comprehensively at the entire enterprise. Often documentation is emitted to link business processes. To eliminate emission, unfortunately, quite expensive investments are needed. Fundamental changes are necessary in the processes of preparing production documentation. The static form must be replaced with the algorithmic form. Today, manufacturing systems need to be prepared for production as soon as possible. The best production cycle is cycle without the laborious process of preparation and distribution of documents in paper form. In addition, the machine control data can be sent directly from the planning system, and the timing and execution monitoring progress could be monitored by computer systems. Both studies and practice have shown usability of the proposed solutions.

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speech therapy, stutter, logopaedics, signal analysis,

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COMPUTER-BASED SPEECH ANALYSIS IN STUTTER

Abstract

The paper presents computer aided approach to speech disorder analysis. The three levels definition of stutter is presented for describing this particular problem. The effective speech analysis algorithm used for segmentation of signal and detecting stutter is discussed and samples are presented.

1. INTRODUCTION

Speech therapy is a science incorporated in many other fields of science. Its interdisciplinary character allows it to reach for modern analysis and description methods. At present, speech therapy diagnosis can be supported by computer software used for both normal and pathological speech analysis. Owing to cutting edge technologies, the diagnosis becomes wider and more accurate, while the therapy is faster and more efficient than with the application of traditional linguistic and mechanical methods. Such techniques find application in virtually all types of speech disorder, especially in stutter, autistic patients or children suffering from alalia (speech delay). Modern computer technology allows programming therapy for persons unable of using active speech through adjusting one of the nonverbal communication channels. Additionally, computer programmes are widely used in biomedical applications [2]. They are extremely useful in diagnosis and classification of voice pathology, allow voice quality monitoring during rehabilitation (e.g. following larynx cancer removal), research on the influence of hearing injuries on speech quality as well as support treatment of speech organs injuries.

Modern electronic multimedia systems can be useful in speech signal analysis and processing in development norms. Specialised computer software allows identifying characteristic speech parameters and accurate voice synthesis [2].

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This is achieved thanks to mathematical description of speech signal (as any other acoustic wave).

This article presents the issue of computer-based speech analysis of stuttering patients, as the support of computer technologies frequently allows full recovery.

2. STUTTER

Stuttering has earned a number of definitions, which present a picture of speech fluency, pace and rhythm disorder caused by discoordination of respiratory, phonetic and articulatory muscles (with possible excessive tension), which may be accompanied by anxiety [6]. This disorder can be extremely stigmatising and may cause difficulties in interpersonal communication as well as functioning in a society. This is caused by the fact that stuttering definition is threefold: linguistic (lack of speech fluency), psychological (logophobia – fear of speaking) and neurophysiological (spasticity) [7].

Nevertheless, the disorder varies from patient to patient in terms of the set of symptoms as well as their intensity [3]. Stutter is a persistent and complicated disorder with continuously unspecified etiology. Neuromuscular disorders seem to be most frequently named as the reason of stutter among the abundance of hypotheses concerning its causes and mechanisms [7]. The fundamental elements of neuromuscular disorders are minimal delays and pauses in coordination of articulatory movements. This, in turn, may cause prolongations and automatic repetitions of parts of words. Additionally, it is commonly believed that stuttering may result from a combination of multiple factors of biological, psychological or even social nature [3].

According to the three levels of stutter description, its definition comprises three different types of symptoms [7]. First of all, it is manifested on the linguistic level as a disrupted flow of speech, as irregular rhythm, frequent sound prolongation, hesitation or pausing before speech as well as pronouncing additional sounds. The psychological sphere encompasses frustration and fear, in particular fear related to the act of speaking, reluctance to speak, the sense of guilt and low self-esteem. The third sphere – neurophysiological – encompasses spastic muscle movements as well as other physiological reactions (including sinkinesis).

To recapitulate, a pause in a standard rhythm and pace of speech, during which the person knows exactly what they intend to say, but, at that moment is entirely unable of articulating their thoughts due to involuntary repetition, elongation or pause of a sound is referred to as stutter [3].

3. STUTTER ANALYSIS METHODS

Speech analysis, both correct and pathological, involves a precise acoustic description, which can be achieved thanks to computer software devised especially for this purpose.

Voice is an individual feature, typical of a specific person. It can be characterised by a specific height of the basic pitch and variable frequency of subsequent formants. The frequencies of particular formants are closely related to timbre, which is also determined by the structure and arrangement of resonators (larynx, pharynx, oral and nasal cavity, paranasal sinuses, thorax) [1].

To date, speech analysis based on merely subjective assessment of speech quality. Rapid technological development has enabled recording speech and subjecting it to objective assessment based on the analysis of physical parameters of particular sounds [1].

In the case of stuttering patients articulatory changes, resulting from muscle spasms, are noticeable. These may be observed in spectral and cepstral analysis results. The speech disorder analysis is conducted by speech signal segmentation and parameterisation of obtained speech sample sequences. The parameters which are subjected to analysis are: the frequency of laryngeal tone (fundamental frequency) and formants frequencies and amplitudes [3].

In speech assessment the disordered speech is characterised by the fluctuation apparent in such format parameters as amplitude and frequency. In normal speech such fluctuations are considerably lower. Loss of formants or emergence of additional formants in frequencies unrelated with the uttered vowel may be observed in disordered speech. The aforementioned stem from uncontrollable voice box muscles spasms [3].

The development of modern methods of stutter detection provides higher precision in recording particular occurrences of disorder, to date based on methods of subjective assessment of speech quality. Regardless of the type of stutter (single sound, syllable or word repetition), special algorithms employing correlation analysis are applied in case of repetition detection (as in Fig. 1). This method of speech analysis automatically detects the place where the repetition occurred by indicating maximum value of the autocorrelation function. The procedure begins with the parameterisation of the stuttering patient's speech by the segmentation of the signal and calculation of the energy of each of the marked segments according to the formula:

$$E = \frac{1}{l}\sum_{i=1}^{l} p_i^2 \tag{1}$$

where:

E – segment energy,

l – the number of samples in a given segment,

p_i – normalised value of the subsequent sample.

The subsequent stages in repetition detection comprise: a) correlation analysis of particular parameters and b) control of exceeding the threshold value of the autocorrelation function. Research conducted at Gdańsk University of Technology show that the effectiveness of automatic detection of repetition amounts to 77% [3].

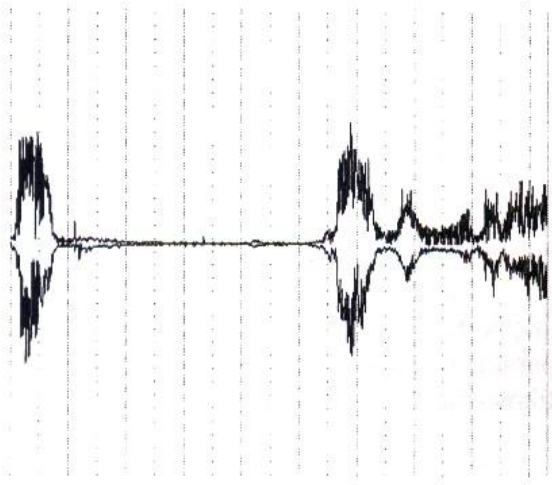

Fig. 1. 'Ad_admiral' sequence with the repetition of the anlaut syllable [3]

Acoustic analysis of speech of stutterers has developed methods of phonation break detection. The detection method of these speech phenomena in stutterers includes: speech signal segmentation, equalising energy levels of higher-frequency components and calculating average signal energy (according to the formula, as in repetition). The programme then calculates upper and lower value of the energy state for each component. These values allow determining the trailing edge preceding phonation break. The trailing edge describes energy decrease rate. It has emerged that phenomena of such type are characteristic of patients with speech disfluency and occur as a consequence of speech muscles spasms, stopping articulation of subsequent sounds of a given speech signal. In stuttering patients, the decrease rate of recorded trailing edge of the energy function is significant, whereas in non-stutterers the envelope of energy function preceding phonation break decreases gently [3].

Protracted articulation, particularly connected with vowels, constitutes another feature distinctly characterising the speech of stutterers. The analysis of elongation of vowels is considerably uncomplicated as the time segment when particular parameters change is extensive and, therefore, enabling high precision measurement.

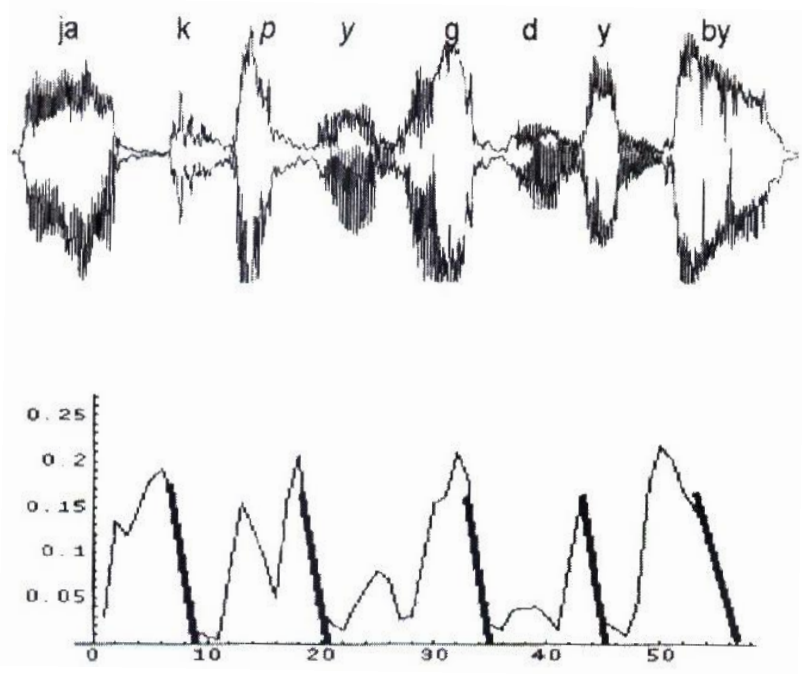

Fig. 2. The rate of decrease of the trailing edge preceding phonation breaks [3]

From the viewpoint of acoustic analysis, these are speech disorders involving the repetition of syllables or vowels which prove more demanding. The prevailing reason for the inconvenience of such measurements is that the articulation time of voiced phonemes is considerably shorter, which results in a significantly smaller amount of information obtained from the analysis of a single recording of the disorder [3].

4. WAVESURFER – SPEECH SOUNDS ANALYSIS SOFTWARE

WaveSurfer is one of solutions for conducting research on speech samples. It is an Open Source tool (such as MySQL or OpenOffice) which enables sound visualisation (mainly speech analysis) as well as its further manipulation and processing. Owing to uncomplicated interface, both beginners and experienced

users will easily find and apply desired functions. WaveSurfer can be used as a stand-alone tool or become an element of advanced sound processing platform, which can be achieved by additional installation of custom plugins or by embedding its components in other applications. The most recent version of the programme, i.e. WaveSurfer 1.8.8, can be downloaded free of charge from WaveSurfer home page: http://sourceforge.net/projects/wavesurfer

WaveSurfer 1.8.8 features:
- type: Freeware
- size: 1.58 MB
- OS: w98 WNT w2000 wxp
- software language: English

WaveSurfer is equipped in numerous features for sound processing, including the following:
- Waveform – a graph representing the shape and form of an analysed sound wave in time.
- Spectrogram – is a graph representing the amplitude spectrum in time. The horizontal axis represents time and vertical – frequency (default in kHz).
- Intensity (the amount of energy in spectrum) is represented by the degree of saturation in given frequencies.
- Formants – lines representing the course of particular formants. Each formant is marked with a different colour.
- Time – a time bar which allows keeping track of sound time.
- WaveBar – a bar for scrolling across the recording – it facilitates sampling.

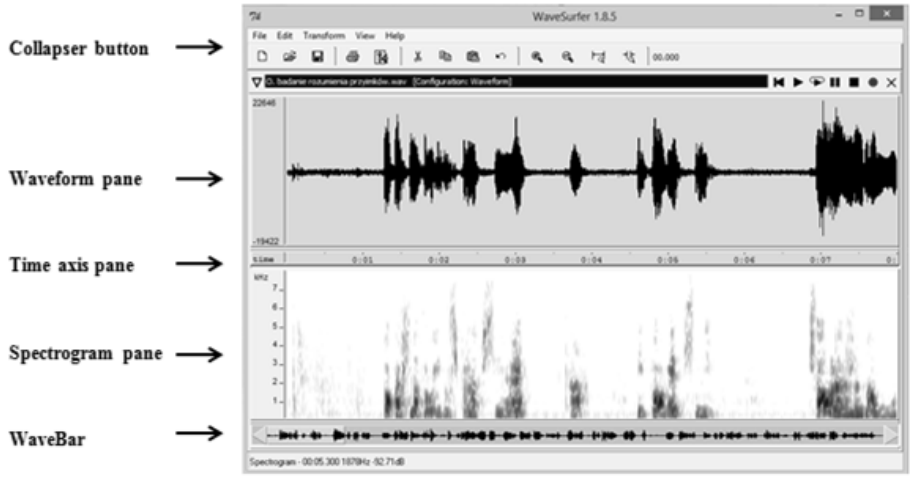

Fig. 3. WaveSurfer user interface [source: own study]

One of numerous features of WaveForms tool is creation of spectrograms, using which a speech therapist, or any other researcher dealing with speech analysis, is presented with a precise record of particular sounds in articulation and can therefore evaluate it and compare with model patterns. The image may prove valuable not only for the therapist but for the patient as well, for whom it can provide the source of feedback, considerably helpful in auto-correction (a system employing auditory feedback in stutter therapy).

The spectrogram record is a two-dimensional representation of the 3D reality. The horizontal axis comprises values referring to time (in milliseconds) while the vertical axis – spectrum elements values connected with frequency analysis (in Hz). The third dimension is visualised by the degree of saturation of image in black or colour. This dimension refers to the intensity of persistence of an analysed element in a given frequency [4].

To present differences in spectrograms in the case of stutter, two utterances are compared – fluent and non-fluent.

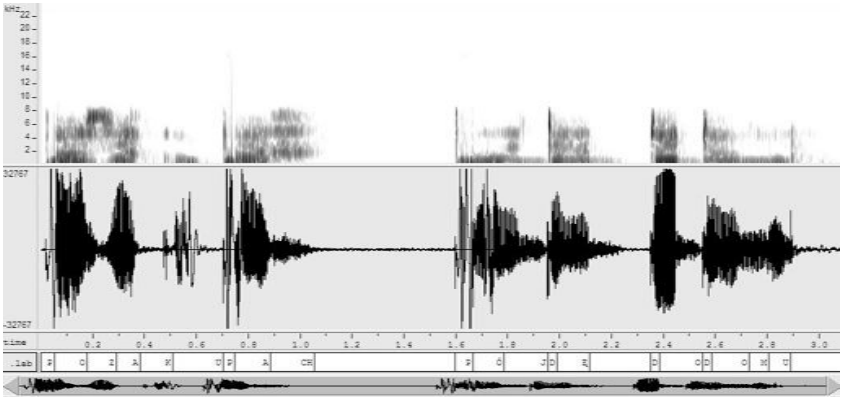

Fig. 4. Fluent utterance: "Po zakupach pójdę do domu" (I'll go home after shopping) [source: own study]

In non-fluent utterance the wave and its spectrogram distinctly show numerous repetitions of 'p' sound as well as 'po' and 'do' syllables, both typical in repetition of the anlaut sound or syllable stutter. Moreover, by increased saturation the spectrogram shows the amount of energy present in repetitions.

What is more, WaveSufrfer software allows the user to cut and manipulate the material as required. The prepared samples can be subsequently compared. In the case in question, the comparative analysis could, for instance, delve into the differences between the correct and non-fluent utterances of 'po' syllable. Another method of examination could consist in comparing the syllables in the course of repetition of non-fluency – whether their times, volume or formants are identical or different, even though the samples have been obtained from the same patient.

Both utterances differ also in total time of utterance as well. Fluently uttered "Po zakupach pójdę do domu" lasted 2.9 s, whereas in the case of stutter, the time was naturally longer, and equal to 5.9 s. The direct comparison of the preceding figures fails to represent the time span of both utterances in an ideal way (different time scale applied), which leads to the necessity to visualise full sentences.

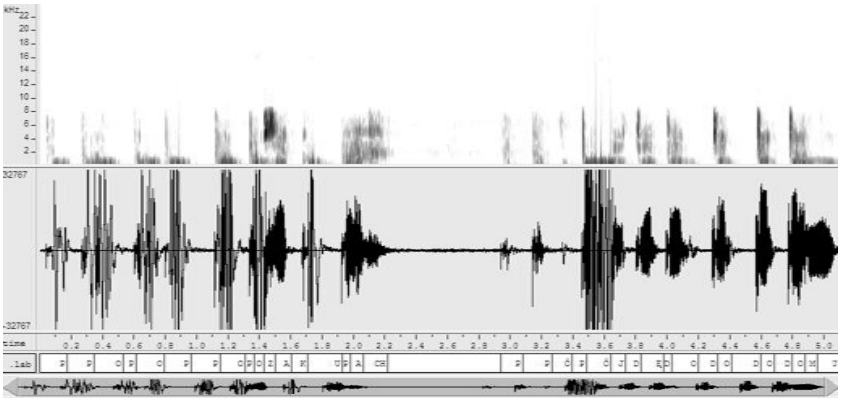

Fig. 5. Non-fluent utterance: "Po zakupach pójdę do domu." (I'll go home after shopping) [source: own study]

As it was presented, WaveSurfer is a programme combining the simplicity of operation with a number of useful and extended functions. What it provides is genuinely in-depth analysis of data, i.e. speech sample, in the area of a researcher's interest. What must not be forgotten is the fact that the programme is freeware, which adds to its unquestionable advantages.

5. CONCLUSION

Computer-aided speech analysis plays an important role in modern-day logopaedics. The application of cutting edge methods of speech analysis enables the therapist to provide the patient with more precise diagnosis, and it, moreover, facilitates speech therapy process. Modern software produces repeatable results which can be represented by numerical or graphical data, suitable for comparative studies and, therefore, is applicable in different fields of science. Computer acoustic speech analysis of stutterers enables notable and objective evaluation of changes in the speech signal structure, and increasingly accurate tests provide the insight into mechanisms accompanying the stutter phenomenon.

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Make to Order production, TOC, moving bottleneck, backward and forward scheduling

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IDENTIFICATION OF BOTTLENECKS IN THE UNIT MAKE TO ORDER PRODUCTION

Abstract

Since the production is aimed at fulfilling specific needs of demanding customers and not at filling warehouses, the production volume should reflect the volume of orders. In times of fight for the client every order has to be performed on time. What is more, in times of fight for shortening the delivery cycle, meeting safe deadlines, that is distant in time, is not enough. Companies are forced to meet short deadlines with keeping the product price competitiveness condition. It is hardly possible without a advanced planning support system. Currently, advanced planning systems are coming into use, however their cost exceeds the possibilities of small and medium enterprises and algorithms used often require great customization to industries' needs and conditions of unit and small-batch production. Such conditions lead to a need for simplified methods. The methods used so far are not capable of finding the global optimum of such big data ranges. For this reason computer tools for applying to the industrial scale are needed. The above method basis on the data so far collected in ERP system.

1. INTRODUCTION

The guarantee of success on contemporary, more and more competence-driven and changeable market is fast and flexible implementation of production processes, which also assures immediate adjustment of production to changes both of the environment and more and more demanding customers. If the 70's

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were the times of costs reduction, the characteristic of the 80's was quality improvement, the 90's were focused on flexible production, the beginning of the 21st century is characterized by focus on customer's satisfaction [7, 1, 12, 10, 11], This trend translates into production of articles adapted to customer's needs and to shortening the availability of products – very often below the production cycle. To implement the tasks connected with production control in such conditions it is necessary to develop operational plans determining the order of production tasks performance by individual production sections. For the plans no to be a chance set of tasks it is necessary to order them properly and to optimize the course of processes. Production control in the moving bottleneck is particularly important. For the solution to this problem authors suggested simplified method based on "back" or "forward" scheduling strategy.

2. STRATEGIES OF ORDERS SCHEDULING

There are many algorithms used to solve scheduling problems, which can be divided into two main groups: optimization (exact) and approximation (approximate). The first group are algorithms, which ensure finding an optimal solution. From a practical point of view, when we solve the problems for a larger scale we apply only approximation techniques that do not guarantee finding the optimum, but require fewer resources and they are faster. The main problem in approximation algorithms is "getting stuck" in one of the local extremes. The main strength of this type of algorithms is finding a feasible "good enough" solution. The group of approximation methods may also includes algorithm presented in the following subsections. A key element of this method is scheduling - a function used to determine the time and the allocation of tasks to the resources of the manufacturing system. One of the tasks of scheduling function is to determine the length of the manufacturing cycle [10, 11].

In determining the order of realization of the tasks two strategies for scheduling are basically used – "backward" and "forward" strategies. In some practical solutions mixed method, which is a combination of these two strategies, is also used.

Depending on the purpose, i.e. the type of asked question, one of the (following scheduling strategy) "backward" or "forward" scheduling strategy is used [12] .

Backward scheduling answers the question: When at the latest we should start manufacturing operations, to make the tasks on time?

In practice, safety time buffer is usually accurate. This technique is used among others to capture the „bottlenecks" in production flow, being on the basis of management in OPT/TOC strategy. Backward scheduling is based on the assumption of keeping the date of availability of the product for the customer, according to his order.

Back scheduling is based on the following algorithm:

- end date of manufacturing of the finished product is set,
- using Gantt charts (regression of planned production cycle of individual components is made), the desired date of availability of a number of components and the structure of the product is calculated,
- with multilevel structure of products the operation is repeated, until reaching the lowest level, i.e. the level of raw materials subsystems,
- the number of necessary components for a variety products and semi-products is aggregated ,
- calculated demand includes stock of semi-products and resources and progress of the running manufacturing orders.

This means that manufacturing should begin no later than the earliest date of commencement of semi-products production. Using the data of the operations of the manufacturing process, i.e. the time of the task staying on the manufacturing resource, for every operation, the time needed to execute the batch of products, parts or subassemblies is calculated. The need for occupation time of machine (or employees) calculated individually for every product, is summarized in the considered planning horizon for all products intended for production.

Forward scheduling answers the question: When manufacturing of the product will be completed, if you know the date of commencement of the associated manufacturing process?

"Forward" scheduling involves making the following algorithm:

- start of production of the product components, as the earliest possible,
- "forward" calculation of the deadlines for the various operations for every planned to manufacture products using Gantt charts and the structure of products,
- calculation of availability time and quantity of planned to buy materials. With multi-level structure of products this operation is repeated until reaching the level of finished products.

This procedure enables determination of the earliest date of products availability. Using the available data of the operation of the manufacturing process, the time of the task staying on the manufacturing resource, for every operation on a specific machine or line the time needed to manufacture the batch of products, parts or subassemblies is calculated.

Scheduling techniques are also used for resource burdens equalization, which aim is as large as possible and evenly production capacity utilization. This aim must be achieved assuming proper distribution, in time, dates of manufacturing orders realization, but distribution, which respects specified time of orders realization. Due to the occurrence of overloads of critical resources, in practice, this balance will never occur. These overloads result in lengthening

the production cycle. Calculation of material resources along with balancing the planned workstations load allows to assess the feasibility of the assumed plan. The calculation takes into account the available production capacities and calendars of machinery and equipment availability. In small and medium enterprises, where the dominant rule of management by projects is usually reduced to the simultaneous handling two or more orders [2] using of these scheduling techniques is particularly desired functionality. The result of the scheduling function is the main manufacturing schedule defined in information management ERP systems, as Master Production Schedule (MPS). In terms of the cost of the process realization, the best solution is the back scheduling method.

3. IMPLEMENTATION OF SCHEDULING ALGORITHM FOR BOTTLENECK LOCATION

Let us assume, that the order involves making a class of homogeneous products in a limited time in the system, in which at the same time other manufacturing orders can be carried out. Order model takes into account the processes in the system and reflects the needs of the customer. Manufacturing order is determined by: the size of the order, completion date, size of the batch, the route of the flow manufacturing process and operation times for particular system resources [6, 12].

3.1. Elements of the algorithm

Step 1. Scheduling of orders by priority rule.

An input data is a unordered set of orders $Zl = \{Zl_1, Zl_2, \dots, Zl_l, \dots, Zl_L\}$;), $L -$ is the number of orders, l – means the order identifier.

For every Zl_l order the order of realization of scheduling function is determined. It is $\forall_{i,j \in Z}$ defined as sequence constraint, means such constraint $i \prec j$ where $\prec$ operator means sequence constraint. Sequence constraint is not technological constraint but organizational one. Every order is assessed in accordance with the rule $R = \{R_1 \prec R_2 \prec R_3 \dots, R_r\}$, which is an ordered set of organizational rules determining placement of the next order priority in the set being the subject of the scheduling function, r- number of organizational rules. As the priority rule we can assume, for example: delivery date (it is also constraint), client code, for which a package of orders is realized, deterministically defined priority tasks realization time (first large tasks and then small), etc. After scheduling of orders an ordered $Zl' = \{Zl'_1 \prec Zl'_2 \prec Zl'_3, \dots, Zl'_L\}$ set was received, which is a reflection of the Zl set, where $\forall_{Zl_i \in Zl}$ there exists such $Zl'_j \in Zl'$,that $Zl_i \equiv Zl_j'$.

Step 2. Searching for planned completion of the order date.

Starting from the Zl'_1 order planned completion date $Zl'_1 d_1 = \max_i\{Zl'_1 d_i\}$ is searched.

Step 3. A search of tasks according to the rule of linkages of the manufacturing process constraint, starting from the highest level.

For $Zl'_1 = \{J_{1,1}, J_{1,2}, \dots, J_{1,n}\}$ order rank order of job tasks according to the order resulting from the technological constraint is made. Every $J_{1,i}$ task, which realization means realization of order is searched. It is usually the task from the highest level of product structure, usually a task assembly job. For $J_{1,i}$ task $J_{1,i}\, d_i = Zl'_1 d_1 - Zl'_1 T_{buf}$ completion date, where $Zl'_1 T_{buf}$ is time buffor of Zl'_1order. To calculate the size of the buffor we can use Drum-Buffor-Rope (DBR) techniques taken from Theory of Constraints (TOC).

$J_{1,i} \equiv J'_1$task, where $J' = \{J'_1 \prec J'_2 \prec J'_3, \dots, J'_n\}$ which is an ordered set of J tasks, according to technological ordering where $\forall J_i \in Zl$ exists such $J'_j \in J'$, that $J_i \equiv J'_j$.

Step 4. A job task sequencing of operations according to order of realization (according to order of manufacturing process).

For J'_1 task, consisting of a set of O_1^i operations carried out on groups of workstations (M^a) $J'_1 = \{O_1^1, O_1^2, \dots O_1^i, \dots, O_1^n\}$ order of operations realization is analyzed.

Operations in the area of tasks must be carried out in given technological order ie. every i operation should be done after i-1 operation, and before i+1 operation. To simplify the notation set of operations of j-th task is similarly determined by O_j. For $\forall i \in O \stackrel{\text{def}}{=} \bigcup_{i=1}^{N} O_j$, O_1^ioperation, which should be carried out as the first one is searched. For simplicity, it is determined as O_1^N. Date of completion the operation $O_1^N\ d_N = J_{1,1}\ d_1$ completion, where N is the last operation in the process for $J_{1,1}$ task.

Step 5. Obtaining the duration of the operation with considering the advancement.

For O_1^N operation, from J'_1task, of Z'_1 order, duration of $p_{v_k N}$ operation is searched, where:

p_{ik} – processing time of *i* operation by *k* variant ($1 \le k \le m_l$,) ,

v_k – way of the operation (decision variable), $v_k \in \{1, \dots m_l\}$.

The following variables have an impact on the $p_{v_{kj}}$ value:

t_{j_i}– unit processing time of i-th technological operation,

T_{pz_i} – setup time of *i*-th technological operation,

t_{tr_i} – time of successive transport operations,

$n_{obr\ Zlec}$ – number of pieces in the batch in order,

$n_{obr\ Com}$ – number of made pieces in the batch,

R_{ComO_i} – advancement rate in % of realized $O_i$operation. If the task is made completely $R_{ComO_i} = 1$ (100%).

Generalizing for every O_i operation its duration is calculated according to formula:

$$(\forall i, v_k \in \{1, \dots m_l\}) : p_{v_k i} = \begin{cases} T_{pz_i} + n_{obr_i\ Zlec} * t_{j_i} + t_{r_i}\ ;\ \text{for}\ \ R_{ComO_i} = 0 \\ \left(1 - R_{ComO_i}\right) * t_{j_i} + t_{r_i}\ ;\ \text{for}\ \ R_{ComO_i} \neq 0 \text{ i } R_{ComO_i} \neq 1 \\ t_{r_i};\ \text{for } R_{ComO_i} = 1 \text{ and } R_{ComO_{i+1}} = 0 \\ 0;\ \text{for } R_{ComO_i} = 1 \text{ and } R_{ComO_{i+1}} \neq 0 \end{cases} \quad (1)$$

$$R_{ComO_i} = \frac{n_{obr_i\ Com}}{n_{obr_i\ Zlec}} \quad (2)$$

Step 6. The calculation of the date of operation commencement

Cycle the manufacturing process of a single batch of the product or element can be organized according to the methods: serial, parallel, serial-parallel. For every of these methods calculating the date of commencement of operations will be different. In the method of backward scheduling: for O_1^N operation, from J'_1 task, of Zl'_1 order it is assumed that $O_1^N C_N$ - means date of completion of N operation (last in process) is equal $O_1^N C_N = O_1^N d_N$, desired date of completion of operation.

Starting from the relation:

$$C_i = S_i + p_{v_k i} \quad (3)$$

transforming it into:

$$S_i = C_i - p_{v_k i} \quad (4)$$

we are looking for S_i, where:

S_i – date of operations commencement (decision variable),

C_i – date of operation completion.

Relation, which is determined by formula (4) can only be used for the serial system of process organization in a system where there are no resource constraints. For other conditions, more complex formula should be used:

$$S_i = C_i - \left(p_{v_k i} - p'_{v_k i}\right) - p_{con_m i} \tag{5}$$

where:

$p'_{v_k i}$ – time of shortening of *i* operation cycle by *k* way resulting from the overlapping realization of operations ie. using parallel, serial – parallel methods when:

$$p'_{v_k i} < p_{v_k i} \tag{6}$$

$p_{con_m i}$ – time of cycle elongation resulting from resource constraints. The next steps the above dependents will be calculated.

Step 7. Checking the resource constraints

Extension of the time of operation O^i commencement has its source in constraints of availability of reusable and consumable resources. In case of O^N operation, which is last operation the problem mainly concerns resource constraints resulting from the availability of the machine being the main reusable resource. The number of machines of the same type, work schedule and work regulations define availability of reusable resource. If $M^a = \{m_1^a, m_2^a, \ldots, m_B^a\}$; then m_i^a workstation is defined by

$$m_i^a = (Ca_i^a, R_i^a, A_i^a) \tag{7}$$

where:

a – means the type of workstation (the group of workstations, which may realize operation of manufacturing system),

Ca_i^a – means resource constraints resulting from the work schedule of workstation (holidays, repairs, renovations of particular machines),

R_i^a – means resource constraints resulting from the work regulations of workstation (shift work, different systems of working on Saturdays, working overtime),

A_i^a – means the number of workstation of type A, i.e.

$$p_{con_m i} = f(Ca_i^a, R_i^a, A_i^a) \tag{8}$$

Due to the clarity of calculation and simplification of algorithm is assumed that:

$$p_{con_m i} = \alpha_i^a * p_{c_m i} + \alpha_i^a * p_{R_m i} \tag{9}$$

where:

a – means the type of workstation (the group of workstations, which may realize operation of manufacturing system)

$p_{c_m i}$ – time of cycle elongation resulting from availability according to work calendar.

$p_{R_m i}$ – time of cycle elongation resulting from availability according to work regulations.

α_i^a – coefficient resulting from the number of machines of the same type.

In the next steps calculation of $p_{c_m i}, p_{R_m i}, \alpha_i^a$ is done.

Step 8. Updating the time of starting the preceding operation

Assuming that in method of backward scheduling: for O_1^N operation, from J'_1task, of Z'_1 order it is assumed that $O_1^N C_N$ - means date of completion of N operation (last in process) is equal $O_1^N C_N = O_1^N d_N$, desired date of completion of operation.

Making S_i calculations according to (5) relation we receive $O_1^N S_N$. Moving further back according to the structure of the manufacturing process, it is assumed that the date of completion of the operation (N-1) is equal to the date of commencement of operation (N) with respect to organizational constraints such as the average shift resulting from the documentation availability or from technological waiting such as drying after painting.

$$O_1^{N-1} C_{N-1} = O_1^N S_N - p_{Org_N} \tag{10}$$

where:

p_{Org_N}– time of cycle elongation resulting from organizational constraints.

Step 9. The next operation

If there is next operation for the (given) task, go to step 5, otherwise go to step 10.

Step 10. The next task/job

For J'_n tasks, the pre-job J'_{n+1} is searched. $(J'_n \prec J'_{n+1})$.

If there is a next task, date of completion of the last operation for this task is calculated, otherwise go to step 11.

The date of commencement of first operation of task (J'_n) is equal to the date of completion of the last operation (J'_{n+1}).

$$O_n^N \; C_N = O_{n-1}S_1 \tag{11}$$

Go to step 5.

Step 11. The end of algorithm

4. CHARACTERISTICS OF BOTTLENECKS IN UNIT AND SMALL BATCH PRODUCTION

In conditions of systems, where unit and small batch production is dominant there is often a problem of bottleneck with variable nature. It means that the bottleneck moves. At some workstations it will appear periodically, on the other chronically, and at some it will appear rarely or never. According to the proposed methods, identification of bottlenecks is done by using the scheduling function of the backward direction, method without labor resources constraint. Typically, for manufacturing orders job tasks are initially generated, in a variant defined as main. Such variant is usually optimal variant in static meaning. Imposition of back scheduling function prepared in this way tasks allows for determining the dates of realization in the latest possible date. Due to scheduling without constraints, we can identify overloads of individual resources occurring at specific time periods.

Contraventions of the availability of resources are analyzed on a weekly or daily tome period. Adoption of lower density of time intervals e.g. monthly, would be subject to too many errors. There could also be situations, that the sum of the month would lead to no overloads. However, it was decided not to take into consideration shorter periods of time, because this kind of contraventions can be discharged using the another organizational methods. To identify bottlenecks in the tested time periods, a procedure presented in the next subsection was used. Operation of procedure for detecting critical enterprise resources consists in determining the overloads, aggregated into τ weekly intervals and types of M^a resources. The first step of the method is to calculate the availability of types of m^a resources, on the basis of data taken from the ERP system and authorial procedure [9, 8, 12].

5. THE PROPOSED ALGORITHM FOR THE REMOVAL OF BOTTLE-NECKS

Because unit and small batch production is focused on meeting the specific needs of demanding customers, the production size must copy the size of orders. Every order must be realized in deadline for its completion. In conditions of permanent shortening the delivery cycle is not enough to meet the safe deadlines i.e. very distant in time. Enterprises are forced to meet the short deadlines with the condition of maintaining the competitiveness of the price of the product. Without proper support computer system carrying out the planning is practically impossible. Now, advanced planning systems are applied in practice, however, their cost is too high for small and medium enterprises, and used algorithms often require a lot of customization to the needs of industry and conditions of unit and small batch production. Advanced Planning System (APS) are an extension of the base functionality of ERP systems. One of the main problems to solve is optimization of serving and dealing with constraints algorithms with taking into account business objectives of enterprises [12].

This paper contains proposals for optimizing the production plan of actual enterprises and descriptions of the problems confined to the conditions set out above.

5.1. Removing bottlenecks by automatically selecting an alternative process in accordance with the "throughput accounting"

The subject of production management is to make decisions on a regular basis so as to effectively and timely realize short-term tasks in accordance with enterprise strategy. To realize these task, it is necessary to build operational plans, which are responsible for order of manufacturing tasks realization by individual cells (types of resources). In order to plans were not a random set of tasks, scheduling function is used. The task of scheduling is therefore prioritizing tasks in a given workstation in a specific order. Due to the limited production capacity, tasks can not be realized simultaneously, but in a specified sequence. None of the used scheduling methods is not able to arrange the order of the tasks so that there are no interruptions - time buffers which should compensate for disruption. A unique workstation is a bottleneck, for which the schedule is continuous [8, 9, 12]. For such defined conditions the task was formulated as follows:

Development of operational plan of work of machines and workers, so as to meet customer requirements (to meet confirmed deadlines) and in the computational abilities, to make optimization of bottleneck work schedule.

Due to the nature of the task, i.e. difficulty to get a global solution, optimal for scheduling problem with this number of tasks and resources, enterprises have focused on approximate method. In order to obtain a good enough solution that

meets constraints of date of orders realization and the local optimization, enterprises have focused on the work of bottleneck and possibility of shortening the date by tasks scheduling on the basis of the additional features of the manufacturing process.

5.2. Choice of manufacturing process in accordance with the planned load of moving bottleneck from an alternative variants

In the practical realization enterprises focuses only on the critical resources. From entire set of tasks and resources analysis was done only for those types of m^a resources for which the following condition is fulfilled [6]:

$$\sum_{k=1}^{K}\sum_{n=1}^{N}\left({}_{k}^{n}tpz^{\,a}+{}_{k}^{n}tj^{\,a}\right) > Fnor^{a} \tag{12}$$

where:

${}_{k}^{n}tpz^{\,a}$ – setup time used on type of m^a resource,
${}_{k}^{n}tj^{\,a}$ - processing time on type of m^a resource,
$Fnor^{a}$- resource availability for type of m^a resource,
n – means operation identifier for J_k job,
k - means job identifier,
N – number of operation,
K – number of jobs.

On the basis of the above formula Λ^a overload for type (group of workstations) of m^a resource is calculated. Calculating of overload in the global system is too vague in terms of operational production plan. It is therefore necessary to take a certain period of time (τ) determining the density of the timeline. Overload is calculated according to relation:

$$\Lambda = \left[{}^{\tau}\lambda^{a}\right]_{\substack{a=1,\ldots,A\\ \tau=1,\ldots,\mathrm{T}}} \tag{13}$$

where:

$$ {}^{\tau}\lambda^{a} = \begin{cases} \sum_{k=1}^{K}\sum_{n=1}^{N}\left({}_{k}^{n}tpz^{\,a}+{}_{k}^{n}tj^{\,a}\right) - if\ m^a\ in\ \tau\ period\ is > Fnor^{a} \\ 0 - \text{otherwise} \end{cases} \tag{14}$$

and:

A – d number of resource types,
τ – planning period,
T – number of planning periods.

The problem to be solved is the density of division of the timeline. On the basis of analysis it was decided take τ period equal one week.

5.3. Experimental research

The research was done in the unit Make To Order production system. Appropriate samples concerning production system were taken from the SME enterprise. Input data come from accumulated data bases of the REKORD.ERP system.

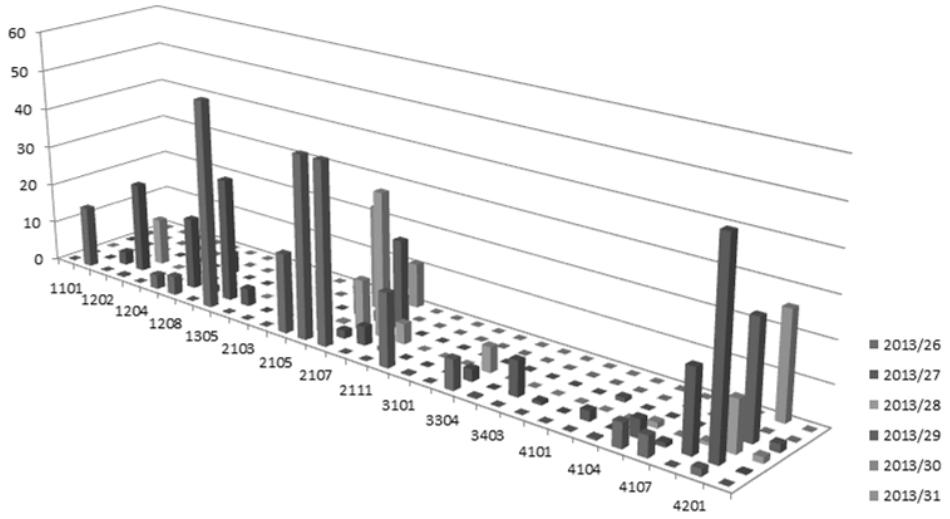

Fig. 1. Graph of tasks' overloading in the week's period [source – own study]

Fig. 1 show graph of tasks' overloading in the week's period. Characteristics of moving bottlenecks has been confirmed. The first step of TOC – Identify of constrain was done. The next steps according to TOC are exploit the constraint, sub ordinate everything to the constraint, elevate the constraint, repeat for the new constraint [3, 4, 5].

6. SUMMARY

Backward and forward scheduling control the trade-offs related to producing early in order to obtain maximum resource consumption and increasing inventory, or producing on time but with the less resource utilization. The options available within the supply or production planning methods are very important for the outcome of the plan. In research papers there can be found descriptions of many test problems of tasks ordering. It is difficult to find an example of a problem solved in real conditions of such a number of tasks and job resources. Therefore, the authors have presented the analysis of the problem of tasks ordering on real data in a broad spectrum of many production companies. The authors' aim is not to prove superiority of this method over others. The task was to state usefulness of the method of process alternatives exchange in real conditions. The results below refer to states before optimization and after its application. Providing the above results helped to define the rim conditions of companies in which usefulness of this method is sufficient. Heuristic algorithms cannot be proven using mathematical methods. A number of tests on real data have been carried out to prove this method.

The above method can be called the simulation "on line". This method found application to the industrial scale, as extension of the ERP class system.

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Łukasz SOBASZEK[*]

COMPUTER PROGRAMMING AS A TOOL FOR THE ENGINEERING PROBLEMS ANALYSIS

Abstract

The paper presents the use of computer programming to solving typical engineering problems. First of all, the basic information about the computer programming ideology and types of computer programming languages were outlined. Secondly, the Matlab environment that combines computing, visualization and programming was described. In the final part of the paper the author presented solution of the beam with a uniformly distributed load problem by use of special computer program prepared in Matlab language.

1. INTRODUCTION

Computer is a very useful tool in the engineer's work. Thanks to the computer technology, many of calculations and analyses can be done faster and more efficiently. But sometimes computer software has some limitations. The solution could be an appropriate use of computer programming. Knowledge of programming allows to create unique and original software. The programmer can develop program that will help analyze definite problem. Today there are many programming languages, which help to make full use of the computer.

The one of the programming languages is Matlab language. It is a part of complex environment. In this article the use of this language to solve typical engineering problem was presented.

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2. COMPUTER PROGRAMMING

2.1. Programming ideology

First computers in the world were built to perform concrete tasks. These computers could realize only limited operation. Every change in the process required modification of the machine. Therefore, the idea to communicate with computer by means of special language understood by the digital machines was raised [1].

But it is very difficult to understand machine language. The basic part of computer – CPU (*Central Processing Unit)* – is built like an integrated circuit and it reacts the incoming bit strings. Therefore, it is very uncomfortable to use machine language. To solve this problem people invented symbolic programming languages. It is method of translating words comprehensible to people to words comprehensible to computer machines [1].

2.2. Programming languages

Programming techniques evolved in parallel with the development of computer hardware. Today term "programming language" means language which is compiled or interpreted to machine form and next executed by processor [9].

Generally, there are two kinds of programming languages – low-level programming languages and high-level programming languages.

The first group is characterized by syntax similar to the machine code. Language is build with elementary instructions understanding for CPU. One instruction is one elementary processor operation. The language of this level includes machine code and Assembler [8].

The second group – high-level programming languages – is characterized by the syntax, similar to human language. Programming code is understandable for programmer, but it requires large commitment of CPU (Fig. 1) [8]. This group include many programming languages. The most popular are: Fortran, Cobol, Logo, Basic, Pascal, Simula, C++, C#, Visual Basic, Delphi, Phyton, PHP, SQL, HTML, Java [9, 8].

```
Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.Ever
    If TextBox1.Text = "" Then
        MessageBox.Show("Błąd!")
    ElseIf TextBox2.Text = "" Then
        MessageBox.Show("Błąd!")
    Else
        If RadioButton1.Checked = True Then
            A = CDbl(TextBox1.Text)
            B = CDbl(TextBox2.Text)
            wynik = A + B
            TextBox3.Text = wynik
        ElseIf RadioButton2.Checked = True Then
            wynik = A - B
            TextBox3.Text = wynik
        Else : MessageBox.Show("Błąd!")
        End If
    End If
End Sub
```

Fig. 1. Visual Basic – high-level programming language
[source: own study]

An example of high-level language is also Matlab language, which is a part of interactive environment. Matlab language has a lot of advantages. It helps to solve many numerical, mathematical and engineering problems faster than traditional languages – e.g. C++ or Java.

3. MATLAB ENVIRONMENT

Matlab is a software package which combines calculations, visualizations and computer programming. This software is used in many areas e.g mathematical calculation, numerical algorithms, simulation and modeling, engineering graphics and other [10].

The basic element of Matlab environment is the matrix. Therefore, the structure of the program allows to perform operation on vectors, scalars, real matrixes [6]. Matlab does not require table structures declaration. The use of two-dimensional dynamic matrix helps solving many technical problems, which are described by means of matrixes or vectors. Matlab includes special libraries (named "toolboxes") to solve many specific problems (e.g. Optimization Toolbox, Neural Network Toolbox [3]. It also allows to create own scripts and functions. The name "MATLAB" comes from the words MATrix LABoratory [6].

3.1. Basic elements of Matlab

Matlab package consists of five basic elements:

- Matlab language – it is a high-level programming language, which allows to create small programs and build advanced application. This language

includes function, inputs, outputs services and objective projecting elements.

- Matlab operating environment – it is a tool to manage variables in workspace, m-files, application, data import and export.
- Graphic system – includes high-level function of making two- and three dimensional graphs, image processing functions and allows to create animations. In addition, the system allows to edit graphics and build a graphical user interface.
- The library of mathematical functions – library that contains many mathematical functions:
    - basic functions (e.g. addition, trigonometric functions, complex numbers functions),
    - matrix functions (e.g. inverse matrix calculations),
    - specialized mathematical function (e.g. Fast Fourier Transform, Bassel functions).
    - API interface – it is library for creating programs in C and Fortran languages, which interact with programs written in Matlab language [3].

Work in Matlab may be twofold:

- direct – user work in typical working mode (in the form of "question – answer") (Fig. 2),
- indirect – activities are implemented by means of programs and scripts written in Matlab language. That helps to perform quick and efficient calculations and results presentation.

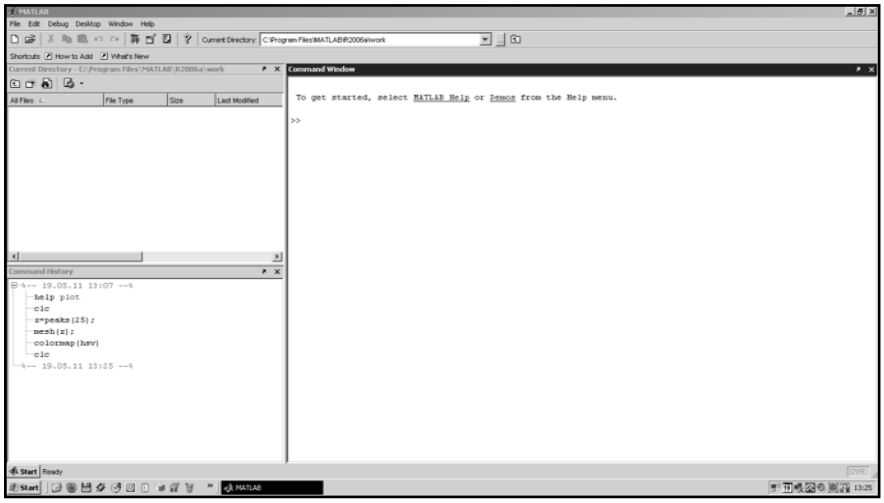

Fig. 2. Direct mode in Matlab [soure: own study]

3.2. Programming in Matlab

Matlab environment allows to create own programs and applications. Computer programming in Matlab helps to use many functions and create programs for solving many engineering problems. Matlab programming language is very clear and simple. It is very similar to the typical programming languages – e.g. C languages.

Prepared codes can be saved in special m-file. This type of file can be prepared and modified in many ways. M-file is a ASCII file with "*.m" extension. Besides the sequence of commands, this type of file may include references to other m-files or to itself. M-file can be script or function file. Script files contain strings of commands. They operate on the variables included in the workspace. The aim of the script files is to insert the data and save the results. M-files with scripts can also include computational algorithms. The second type of files are function files. They contain user-defined functions and operate on local and global variables. Communication with the workspace is via formal parameters and global variables. Function m-file should begin with the key word „function". Moreover, file should contain name of function and list of input parameters [4].

In m-files it is able to use all of the Matlab methods and elements: preparatory functions, arithmetic operations, vectors and matrix operations and graphic functions. In the Matlab language we can use conditional statements ("if – elseif – else – end" and "try – catch – end"), switch statement ("switch – case – otherwise – end") and iterative statement („while – end" and „for – end"). Moreover, instructions "break" and "return" are available. It is very important that the program is interactive. To realize this purpose user can use input/output functions (Tab. 1). In Matlab language, should enter the name of the variable to display the value of the variable.

Tab. 1. Input script functions [3]

Function	Description
x=input('text')	display the text string; waiting to enter a data and assign them the variable x
x=input('text','s')	display the text string; waiting to enter a string and assign it the variable x
pause	stop script execution until the user presses any key
pause(n)	stop the script for n seconds

4. BEAM WITH A UNIFORMLY DISTRIBUTED LOAD

Appropriate use of elements of Matlab language helps to analyze and solve many engineering problems. An example can be analysis of beam with a uniformly distributed load, which is a typical mechanical problem.

4.1. Analysis of the problem

The simply supported beam has a length of *l*. Value of uniformly distributed load is *q* (Fig. 3). The height of rectangular cross-section of the beam is *h* and width is *b* (Fig. 4). Draw the shear force and bending moment diagrams of this beam. Calculate the deflection *f* and the angle of deflection Θ.

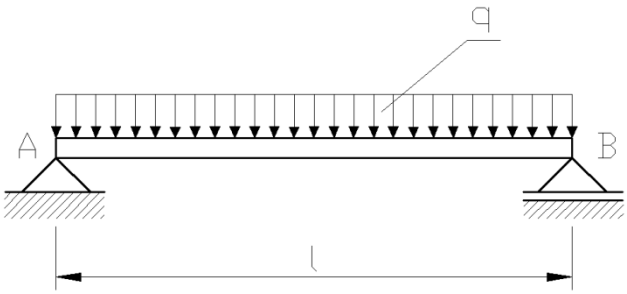

Fig 3. Considered beam [source: own study]

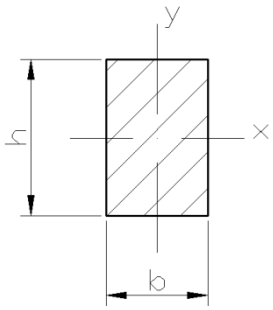

Fig. 4. Rectangular cross-section of the beam [source: own study]

The first part of this problem solve will be determinining the value of the reactions at the supports. For this purpose, uniformly distributed load replaced force $Q = ql$. Because this system is statically determinate, the reaction at the supports are calculated by equations:

$$\sum P_{ix} = 0 \tag{1}$$

$$\sum P_{iy} = R_A + R_B - Q = 0 \tag{2}$$

$$\sum M_{iA} = Q \cdot \frac{l}{2} - R_B \cdot l = 0 \tag{3}$$

where:

ΣP_{ix} – sum of forces in *x*-axis,
ΣP_{iy} – sum of forces in *y*-axis,
ΣM_{iA} – sum of the bending moments relative to the support A,
R_A – reaction at the support A,
R_B – reaction at the support B,
Q – force on the value of *ql*,
l – length of the beam.

Based on the above equations, determined reaction at the support B:

$$R_B = \frac{Q}{2} = \frac{ql}{2} \tag{4}$$

By creating a system of equations is determined reaction at the support A:

$$\begin{cases} R_B = \dfrac{ql}{2} \\ R_A + R_B = Q \end{cases} \tag{5}$$

$$\begin{cases} R_B = \dfrac{ql}{2} \\ R_A = Q - R_B = Q - \dfrac{ql}{2} = \dfrac{ql}{2} \end{cases} \tag{6}$$

where:

R_A – reaction at the support A,
R_B – reaction at the support B,
Q – force on the value of *ql*,
q – uniformly distributed load,
l – length of the beam.

The next step will be to determine shear force and bending moment at a distance *x* form the support A (Fig. 5).

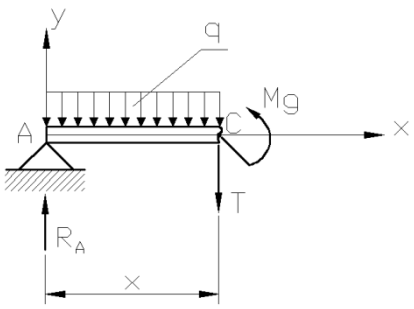

Fig. 5. Shear force *T* and bending moment M_g [source: own study]

The value of the shear force are calculated from the following equation:

$$\sum P_{ix} = 0 \tag{7}$$

$$\sum P_{iy} = R_A - qx - T = 0 \tag{8}$$

hence:

$$T(x) = R_A - qx = \frac{ql}{2} - qx \tag{9}$$

$$T(0) = \frac{ql}{2}$$

$$T(\frac{l}{2}) = 0$$

$$T(l) = -\frac{ql}{2}$$

where:

ΣP_{ix} – sum of forces in *x*-axis,
ΣP_{iy} – sum of forces in *y*-axis,
x – distance from the supports A,
q – uniformly distributed load,
l – length of the beam,
T – shear force.

Graph of shear forces in the beam will be as follows:

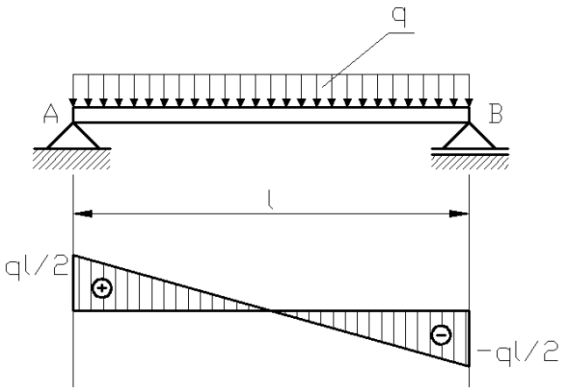

Fig. 5. Graph of shear forces [source: own study]

Value of bending moment is determined on the basis of sum of bending moments relative to the point C:

$$\sum M_{iC} = R_A \cdot x - q \cdot x \cdot \frac{x}{2} - M_g = 0 \tag{10}$$

hence:

$$M_g(x) = R_A \cdot x - q \cdot x \cdot \frac{x}{2} = \frac{ql}{2} \cdot x - \frac{qx}{2} \cdot x \tag{11}$$

$$M_g(0) = M_g(l) = 0$$

$$M_g(\frac{l}{2}) = M_{g\max} = \frac{ql^2}{4} - \frac{ql^2}{8} = \frac{ql^2}{8}$$

where:

ΣM_{iC} – sum of bending moments relative to the point C,
R_A – reaction at the support A,
x – distance from the supports A,
q – uniformly distributed load,
l – length of the beam,
M_g – bending moment.

Graph of bending moments in the beam will be as follows:

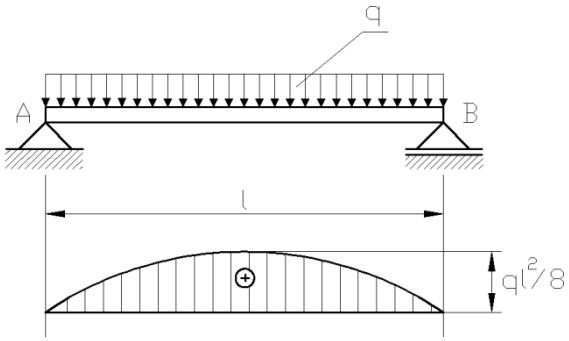

Fig. 6. Graph of bending moments [source: own study]

The deflection *f* and the angle of deflection Θ should also be calculated through analysing considered problem (Fig. 7).

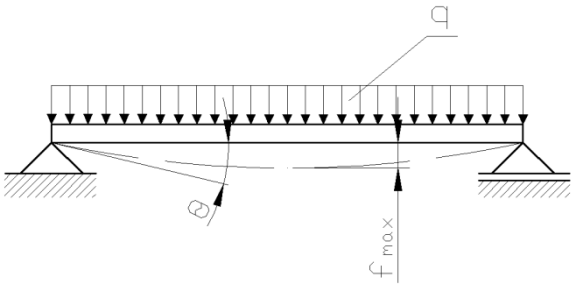

Fig. 7. Deflection *f* and the angle of deflection [source: own study]

These values are determined based on the differential equation:

$$EI\frac{d^2y}{dx^2} = M_g(x) \tag{12}$$

where:

E – Young modulus,
I – moment of inertia,
$\frac{d^2y}{dx^2}$ – the Second Derivatives,
$M_g(x)$ – bending moment.

After performing the necessary calculations (integrating the equation) the deflection and the angle of deflection are determined at any point in beam:

$$EI\frac{d^2y}{dx^2} = M_g(x) = \frac{ql}{2}\cdot x - \frac{q}{2}\cdot x^2 \tag{13}$$

$$EI\frac{dy}{dx} = \frac{ql}{4}\cdot x^2 - \frac{q}{6}\cdot x^3 + C$$

$$EIy = \frac{ql}{12}\cdot x^3 - \frac{q}{24}\cdot x^4 + Cx + D$$

where:

E – Young modulus,
I – moment of inertia,
$\frac{d^2y}{dx^2}$ – the Second Derivatives,
$\frac{dy}{dx}$ – the First Derivatives,
x – distance from the supports A,
y – deflection,
q – uniformly distributed load,
l – length of the beam,
C, D – constants of integration.

Use of the balance beam equations ($y_{(x=0)} = 0$, $y_{(x=l)} = 0$), determined constants of integration:

$$C = -\frac{ql^3}{24} \tag{14}$$

$$D = 0$$

Therefore, deflection and angle of deflection calculated on the basis of formulas:

$$f(x) = y = \frac{ql}{12}\cdot\frac{x^3}{EI} - \frac{q}{24}\cdot\frac{x^4}{EI} + \frac{ql^3}{24}\cdot\frac{x}{EI}, \tag{15}$$

$$f(0) = f(l) = 0,$$

$$f(\frac{l}{2}) = f_{\max} = \frac{5}{384} \cdot \frac{ql^4}{EI},$$
$$\Theta = \frac{1}{24} \cdot \frac{ql^3}{EI}, \tag{16}$$

where:

f – deflection,
Θ – angle of deflection,
E – Young modulus,
I – moment of inertia,
x – distance from the supports A,
q – uniformly distributed load,
l – length of the beam.

Value of moment of inertia I depends on the cross-section of the beam. Young modulus E has different value depends on the kind of material.

Presented analysis were based on publications [2, 5, 7]. The analysis above is a mathematical model of the problem. This model can be very useful during preparation of a computer program. Through using mathematical formulas in common with making programming languages, programmer can develop useful tool to analyze beam with a uniformly distributed load. The program made in such a way helps analyzing several cases of this problem.

4.2. Developed program

The use of MathWorks Company environment allows to prepare computer program which can be useful during analyze above issue. Prepared program was written by use of Matlab and helps to thoroughly analyze the problem of beam with a uniformly distributed load. Program running in direct mode – user see question and next give an answer. User entered all of necessary values and next, the computer program execute calculations.

After starting the program, the user is asked about the value of the geometrical parameters of the beam – length, height, width, and moreover value of the uniformly distributed load. Based on these variables the user gets information about values of the reactions at the supports, shear forces, bending moments, deflection and the angle of deflection.

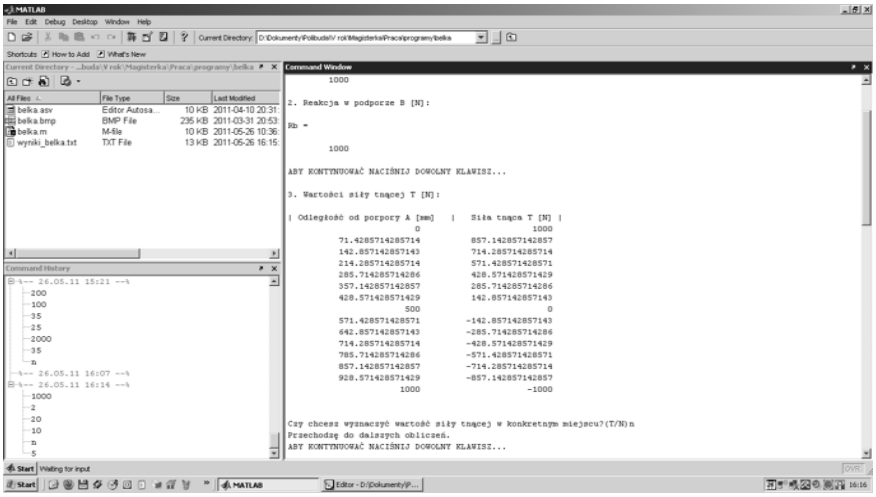

Fig. 8. Calculation of the shear forces [source: own study]

Source code begins function *clear* that deletes all of variables from memory and function *clc* that clear workspace. Function *format* helps define accuracy of the displayed results. The results of program work are exported to text file by means of special function *diary*. All of displayed information are saved in the file *results.txt* in the program directory. The input data is processed to determinate searched values. During entering geometrical parameters of considered beam user can use auxiliary schema of beam. Image is shown by means of function *imshow* and loaded by means of function *imread*. Function *figure* activates special window for auxiliary image.

Program include many conditions in its structure. This helps to avoid many problems and errors. Conditions are achieve by *if* conditional statements. Results are presented step by step. This is possible thanks to the *pause* function. Function *pause* stopped program execution until user press any key on the keyboard. Results displaying precedes function *date* that displays current date.

During the calculation function *linspace* is used. This function allows to express length of beam as vector with predefined number of elements. That helps to determine the value of shear force, bending moment and deflection at different distances from the left support of the beam. Moreover, this function is very useful while generate graphs by the program. Value of the shear force and bending moment could be determinate at a particular point of the beam.

In the developed program the user define kind of material of the beam. *Switch* conditional statements contains few option: steel, cast iron, aluminum, copper, wood or concrete.

After the calculations, program generates the graphs. Graphs of the shear force, bending moment and deflection are showed by means of function *plot*. Graphs are shown in the special graphical window (activated by the command

figure). The developed program allows summary graphs of the deflection of the beams made of different materials (Fig. 9). This option helps to compare different variants of the calculations. Moreover, the relationship between deflection and beam material is presented on the graphs.

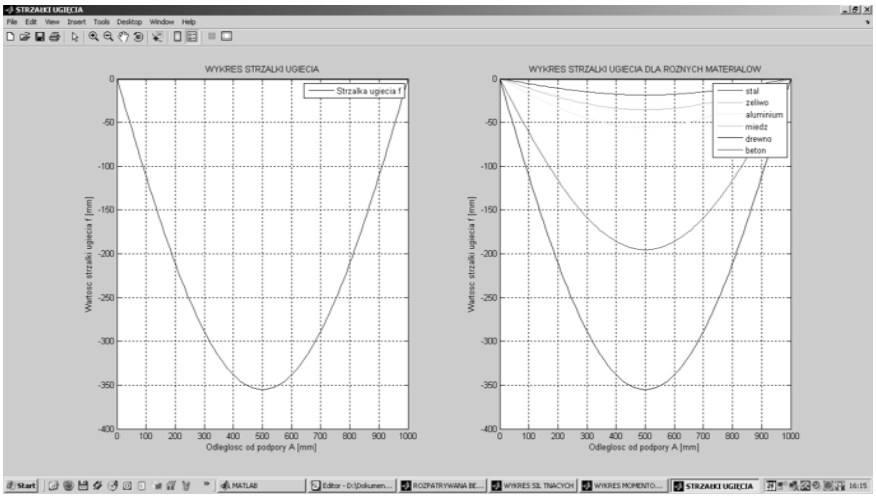

Fig. 9. Deflection of the beams made of different materials [source: own study]

In the end of the program user decide what program should do – run again and make calculation for other data or exit the program. Function *run* starts program from the beginning. Function *quit* close the program.

5. SUMMARY

Nowadays computer is used in many areas of life. It is also a necessary tool in the engineer's work. Computer programming can be very useful in engineer work too. Knowledge of programming allows to create own software and using it to solve many problems. Specially dedicated software accelerates research. There is a lot of programming languages, but Matlab language certainly stands out. Simplicity and ease of this language make that Matlab language is using in many areas. Presented problem is a one of the many, because engineer can also create programs to analyze other issues – e.g. construction problems, machining problems and many other.

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the intellectual potential, integral index of the level of intellectual potential, sustainable development

Iryna MOYSEENKO[*]*, Mariya DEMCHYSHYN*[**]

MEASURING OF INTELLECTUAL POTENTIAL INFLUENCE ON THE ECONOMY OF UKRAINE

Abstract

Methods of the techno-globalism parameters use in the analysis of the state economy are described in the article. Integrated model of the intellectual potential measurement is presented. The dynamics of the economic development macro indicators is described.

1. INTRODUCTION

The state of economic development of Ukraine is characterized by slow development of the market mechanisms, systemic crisis of the social production and lack of the effective state innovation policy that determines low level of economic development, inefficient use of the intellectual potential of the state and economic subjects.

The use of all factors, which influence the macroeconomic innovation environment formation, are necessary to implement the strategy of economic security and development of Ukraine in conditions of techno-globalism processes' deployment.

These factors include: the use of intellectual potential of Ukraine in all sections: fundamental, sectorial and applied spheres; the effectiveness of innovation processes' state regulation; the knowledge economy foundations' formation in the spheres of education, science, technological and information infrastructures.

New interdisciplinary knowledge, generated by scientific and social institutions, high-quality human capital preparation, provided by the education, additional wealth's creation by the knowledge economy and formation of the integral vector of the society development on this basis, aimed at the life quality

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and safety improvement of all members of the society, became integral components of the knowledge society. The increase of the techno-globalism factors role in the state economic development formation determines the modification necessity of techniques and macro modeling models.

New approaches to the economic growth problem consider multi variation of development and emphasize the increase of not only the scientific knowledge role, but also the volume of society knowledge. It is reflected in the calculation method of the intellectual capital index of the state, which is considered as a composite index with a few components: the human capital index, the process capital index, the market capital index, the reproductive capital index. The state intellectual capital dynamics assessment is required to develop an effective innovation policy. Development indicators of the innovation sector of economy also reflect the structure of intellectual capital and include few groups of indexes, which are evaluated: human resources, new knowledge creation, new knowledge use, innovation financing [1].

Integral ratings, which consider the total effect of the techno-globalism aggregate threats on the sustainable development of the countries of the world, are presented in the sustainable development assessment method (MBC), (Sustainable Development Gauging Matrix, SDGM), which determines aggregate index of the sustainable development through next components: economic, ecological and social dimensions. The knowledge economy parameters are shown in terms of social development indexes. The actual data use of sustainable development indicators and parameters for a specific region aimed at taking deliberate decisions at different management levels is one of the important MBCP implementations [2, 3].

The described methods consider separate components of the knowledge economy and techno-globalism, but don't consider the level of intellectual potential of the state.

The absolute and relative increase in domestic spending on research and development work, capital investment in technical re-equipment of enterprises using own and borrowed funds, is taken place in recent years.

Industrial enterprises should intensify contacts with research institutions and universities for the innovation activity increase. The question of the research and development work assessment in industrial enterprises of Ukraine requires further investigation and improvement aimed at the creation of innovation development management model based on the intellectual potential of the state use.

Fig. 1 shows the dynamics of use of intellectual potential indicators and separate parameters of the state economic development. Comparative data analysis helps to identify discrete trends of dependencies, to determine intervals of high level regression relationships and installation directions of indicators of the stimulants and de stimulants of economic growth.

The research done can be viewed as the initial stage of developing macro modeling using the modified list of techno globalism parameters.

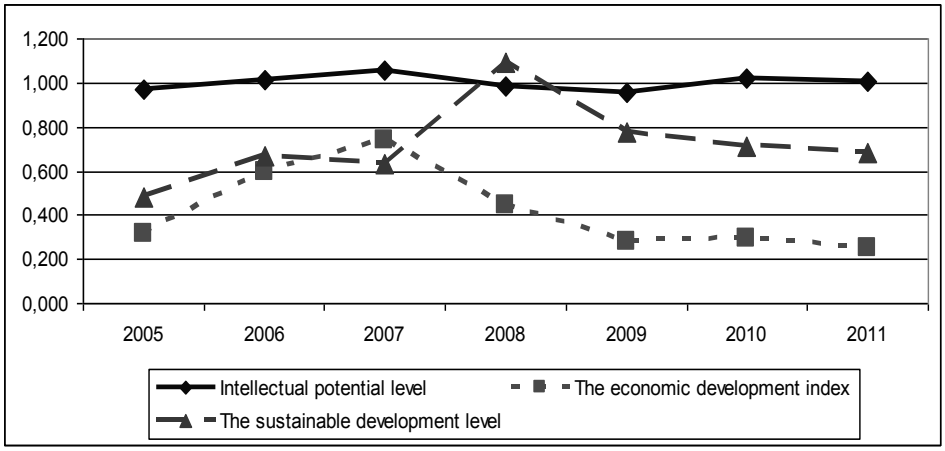

Fig. 1.Comparison of the dynamics of intellectual potential and sustainable development levels [source: own study]

2. PURPOSE OF STUDY

Purpose of this study: to analyze the impact of the intellectual potential integral index on the macro indicators of the economic development of Ukraine.

On the one hand, the modeling process in global economy means the selection of large volume of meaningful units of a certain object, which form together its deepest essence; on the other hand, it means strategy and tactics determination of macro- and micro regulation, aimed to overcome connections which impair existing relationships between the various elements of the system. Thus, adequate economic model reflects both old qualities of the existing before paradigm and some new, which are required by new conditions of the economic development.

Three groups of models are distinguished in scientific literature:

- economic, which include appropriate mechanism and instruments of macroeconomic proportions regulation;
- mathematical, which include modern apparatus of mathematical and fuzzy logic;
- predictive, which allow to predict the growth rates and outcomes of certain changes in the social and economic life of the society using instruments of the mentioned above models [3].

Taking into account the above considerations the integral index measuring the level of intellectual potential is used (1):

$$I_{IP} = \sqrt[3]{I_{OP} \times I_{KP} \times I_{IN}}, \quad (1)$$

where:

I_{IP} – the integral index measuring the level of intellectual potential.

Components' calculations of the intellectual potential level were held using next models of integral indexes:

Tab. 1. Calculation models of the intellectual potential components

Intellectual potential components	Techno-globalism parameters
Education potential level $I_{OP} = \sqrt[4]{\frac{KN}{KNZ} \times \frac{KS}{KVS} \times \frac{OR}{KNZ} \times \frac{RV}{VVP}}$	*KN* – number of scientists; KNZ – number of scientific institutions; KS – number of students; KVS – number of higher education institution; OR – volume of scientific works done; RV/VVP – proportion of completed scientific and scientific-technical activities in GDP,%.
Cultural potential level $I_{KP} = \sqrt[4]{\frac{KV_T}{KT} \times \frac{KV_K}{KKZ} \times \frac{KV_M}{KM} \times \frac{KP}{KB}}$	KV_T / KT – number of visitors /number of visitors, thousands of people / theatre; KV_K/KKZ – number of visitors / number of concert halls, thousands of people / concert hall; KV_M / KM – number of visitors / number of museums, thousands of people / museum; KP/KB – library fund /number of libraries, thousands of units /1 library.
Innovation potential level $I_{IN} = \sqrt[3]{PVP \times PVIR \times PVPV}$	PVP – proportion of enterprises which implemented innovation, %; PVIR – proportion of enterprises engaged in innovation, %; PVPV – proportion of innovative products sales in industrial sales, %.

Influence level of the chosen parameters of economic development can be measured using appropriate regression models, which allow to set the correlation index value and get access to predictive development models. Adequate economic model reflects both old qualities of existing before paradigm and some new, which are required by new conditions of the economic development [3, 4]. Dependencies between economic development indicators and techno-globalism parameters are presented in Fig. 2, Fig. 3, Fig. 4, Fig. 5.

Tab. 2. Datains of the intellectual potential components and economic development indexes

Year	Educational potential indicator	Cultural potential indicator	Innovation potential indicator	Integral indicator of the intellectual potential using	Sustainable development index	Economic development index
2001	1,035	1,074	0,970	1,025		
2002	1,023	1,092	0,962	1,025		
2003	1,111	0,673	0,881	0,870		
2004	1,061	1,297	0,960	1,097		
2005	1,036	0,972	0,902	0,969	0,485	0,319
2006	1,016	0,981	1,047	1,014	0,668	0,595
2007	1,058	1,030	1,087	1,058	0,633	0,741
2008	1,054	1,015	0,888	0,983	1,089	0,442
2009	1,015	0,935	0,917	0,955	0,775	0,283
2010	1,013	1,001	1,050	1,021	0,714	0,294
2011	0,967	1,000	1,043	1,003	0,686	0,255

Linear regression equation coefficient $y = 3{,}6708x - 3{,}2539$ (Fig. 2) allows to affirm that the increase in the level of intellectual capacity of 0.1 can cause the increase in the index of economic development of 0.367. The coefficient of determination $R^2 = 0{,}4776$ shows that change in value of the economic development index depends on changes in the level of intellectual capacity at 47.76%.

Regression model $y = 3{,}6475x - 3{,}3121$ reflects the dependence of economic development index on one of the components of the integral indicator of intellectual potential, namely the educational potential indicator (Fig. 3). According to this model, it is possible to draw conclusions about a significant impact of the educational potential indicator on change in the economic development index.

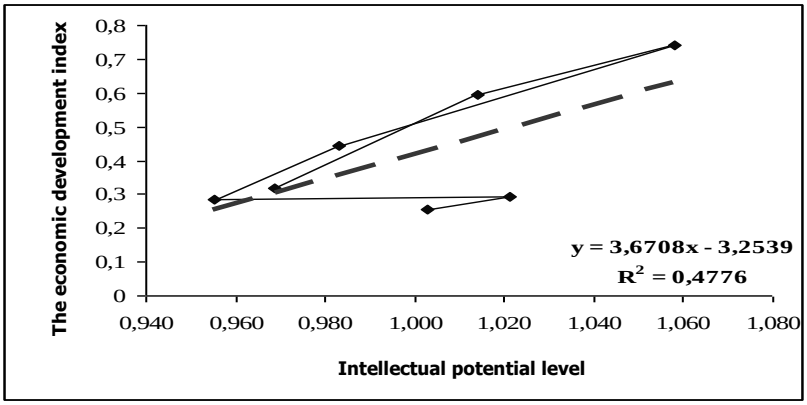

Fig. 2. Influence of indexes of intellectual potential level on the economic development index [source: own study]

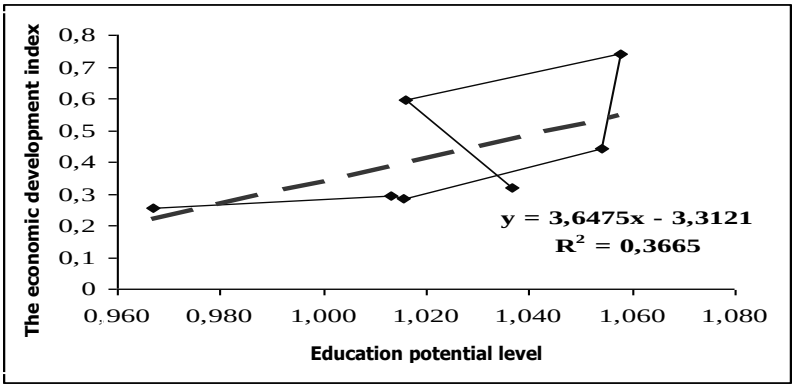

Fig. 3. Influence of indexes of education potential level on the economic development index [source: own study]

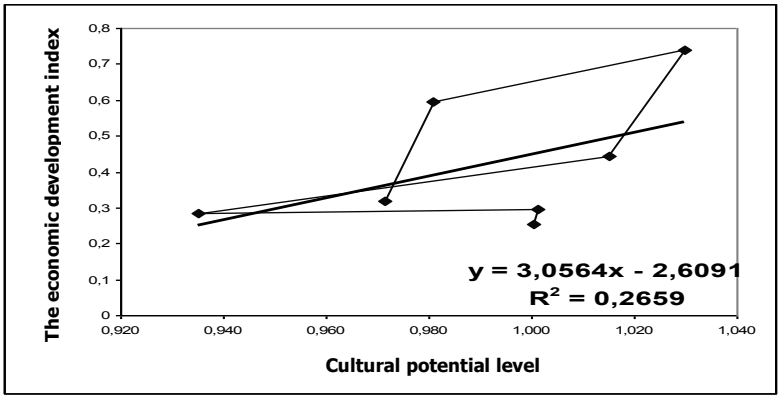

Fig. 4. Influence of indexes of cultural potential level on the economic development index [source: own study]

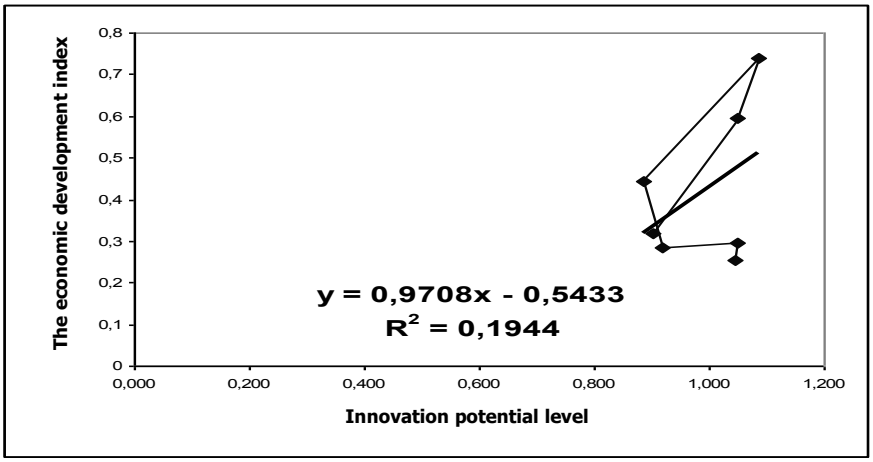

Fig. 5. Influence of indexes of innovative potential level on the economic development index [source: own study]

The values of the coefficient of determination $R^2 = 0,2659$ (Fig. 4) and $R^2 = 0,1944$ (Fig. 5) show that changes or fluctuations in the economic development index by 26.6% depend on changes or fluctuations in the cultural potential indicator and depend on changes in innovative potential indicator by 19,4 %. We can make a conclusion about certain influence of cultural and innovative components of the intellectual potential using level on the economic development.

Regression-correlation analysis of the techno globalism parameters influence on the economic development level makes it possible to assert that the closest relationship is between the amount of expenditure on education and science and the number of implemented innovations. Therefore, increased spending on science and technology fields can be considered as an alternative priority resource of economic transformation. Intellectual investment and spending on basic research show significant but moderate relationship. However, the significance of mentioned factors of the society intellectual potential increase will grow exponentially under the circumstances of the know-how, technology innovation spread in the domestic market.

Research of the influence of intellectual potential index on the economic development of Ukraine allows to suggest that the components of intellectual economy – education potential level (coefficient of determination $R^2 = 0,3665$) are the basis for the overall economic acceleration. Research using regression analysis method allows to suggest that there is the closest relationship between spending on education and science and number of implemented innovations; the level of intellectual potential use influences on the economic development index far more than on the index of sustainable development (coefficients of determination $R^2 = 0,4776$ та $R^2 = 0,0362$ respectively). Thus, the increase in

spending on science, technology and education spheres can be viewed as alternative priority resource of economic transformation. Intellectual investment and spending on fundamental research show significant but at the same time rather modest relationship [4].

3. CONCLUSIONS

The directions of sustainable development of Ukraine in global environment should reflect techno-globalism trends, economic and innovation policies should be based on the analysis and assessment of latest scientific ménage concepts in the context of global ménage dominants according to existing strategic potential of the state. To update the values and goals of sustainable development there is a need to develop innovative approaches that will push the implementation of sustainable development concepts in the coming decades [5].

The research of the influence of the intellectual potential elements on the economic development in Ukraine allows to assert that the components of intellectual economy, scientific and technical progress, the education system, the modernization of the Ukrainian economy, innovation spending and spending on basic research, the development of the intellectual potential of the nation are the basis for the overall acceleration in Ukraine.

The influence of the elements of the intellectual potential of Ukraine on the economy suggest that the basis for the overall acceleration in Ukraine are components of the knowledge economy ¬ NTP, the education system, the modernization of the Ukrainian economy, innovation spending and spending on basic research, the development of the intellectual potential of the nation.

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