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# AN ERP-ORIENTED MODEL OF PROJECT DRIVEN ENTERPRISE

*The paper presents a model of project driven enterprise dedicated for implementation of enterprise resource planning system (ERP) in small and medium manufacturing enterprise that complete engineer-to-order production. The model is consisting of a structure of business processes, resources, orders (projects) and decisions performed in the company. The model is related to the structure of typical ERP system. In the paper procedure and the most important efficiency ratios for the ERP system implementation are proposed that decide about implementation success. Especially the evaluations of ERP implementation based on productivity ratios are interesting.*

## MODEL PRZEDSIĘBIORSTWA ZARZĄDZANEGO PRZEZ PROJEKT ZORIENTOWANY NA WDROŻENIE SYSTEMU ERP

***Streszczenie.*** *W artykule przedstawiono model przedsiębiorstwa zarządzanego przez projekt przeznaczony dla potrzeb implementacji zintegrowanego systemu zarządzania (ERP) w małych lub średnich przedsiębiorstwach produkcyjnych realizujących produkcję typu projektowanie na zlecenie klienta. Model obejmuje strukturę procesów biznesowych, zasobów, zleceń (przedsięwzięć) oraz decyzji podejmowanych w przedsiębiorstwie. Opracowany model został odniesiony do typowej struktury systemu klasy ERP. W artykule zaproponowano procedurę oraz najważniejsze wskaźniki oceny efektywności implementacji sytemu ERP, które decydują o sukcesie wdrożenia. Szczególnie ocena wdrożenia systemu ERP oparta na wskaźnikach produktywności jest interesująca.*

## 1. INTRODUCTION

The research in area of ERP systems are performed in the following streams: analysis of success factors of ERP system implementation, strategy and methodology of ERP system implementation - motivations and expectations, overview of ERP - selection, modeling and development, proposals on how to analyze the value of ERP systems. Hong and Kim [5] define the concept of organizational fit of ERP and examine its impact on ERP implementation on the base of surveys from 34 organizations. Motwani et al. [13] use a case study methodology grounded in business process change theory, to understand the factors that lead to the success or failure of ERP projects. The results from comparative case study of 4 firms that implemented an ERP system suggest that a cautious, evolutionary, bureaucratic implementation process backed with careful change management, network relationships, and cultural readiness have a positive impact on several ERP

implementations. Al Mashari et al. [1] present a taxonomy of the critical success factors in ERP implementation process that measurement takes place in a balanced perspective, and for the purpose of providing useful information that can enable the decision making process and, which can help deliver the corporate objectives and therefore lead the business competitively forward. Mabert et al. [12] on the base of a series of case studies and an extensive survey analyses an impact of different sizes of companies on ERP implementations across a range of issues. The same team of scientists [11], empirically investigates and identifies key differences in the approaches used by companies that managed their implementations on time and/or on/under-budget versus the ones that did not using data collected through a survey of US manufacturing companies that have implemented ERP systems. Wie and Wang [14] presents a comprehensive framework for combining objective data obtained from external professional reports and subjective data obtained from internal interviews with vendors to select a suitable ERP project. A hierarchical attribute structure is proposed to evaluate ERP projects systematically. They use fuzzy set theory to aggregate the linguistic evaluation descriptions and weights. Gulla and Brasethvik [3] propose the model-driven business management approach. The dynamic and adaptable business models is constructed as part of the ERP implementation project and used to access the system and monitor the real business flows.

The decision about implementation of an ERP system is often rash and managers that take the decision into consideration are based on experiences of another companies (mostly from different branches). The presentations of ERP products prepared for top management are very general and include mostly the spectacular results (analysis, decision factors,) of the implementation. Each producer of ERP makes sure that his system fulfills all client requirements and proposed implementation methodology guarantee full success. The independent research organizations that analyze ERP market generally deal with the ERP systems dedicated for middle and great enterprises. The characteristics of ERP dedicated for small or medium companies are residual. There are not tools on the market which enable to support process of selection and implementation of ERP system and that support evaluation of results of the implementation. The software packages for modeling and analysis of business processes (for example ARIS or iGrafix) are useful to prepare the business processes for ERP implementation. The tools should be used for analysis as-is and should-be states before and after ERP implementation relatively. To design the final structure of business processes the ERP system has to be chosen and on the base of possibilities of the system. The functionality of ERP determines the structure of business processes of the company because implementation of different ERP systems can results in another ways of solving the same problems. To evaluate the efficiency of ERP system implementation the set of metrics has to be defined to reflect the most important enterprise characteristics before and after the implementation of ERP. The impact for implementation of ERP in the project-driven enterprise is investigated in the following functional areas of the enterprise: Sale and Distribution, Research and Design, Construction and Technology, Purchasing, Production, Material Management

For each functional area a structure of typical business processes for project-driven enterprise is proposed. The structure of business processes and resources allocated to the business processes build a meta-model of project-driven enterprise. To improve selec-

tion and implementation of ERP, the reference model of the ERP system dedicated for project driven manufacturing should be created. (see the Fig. 1.1).

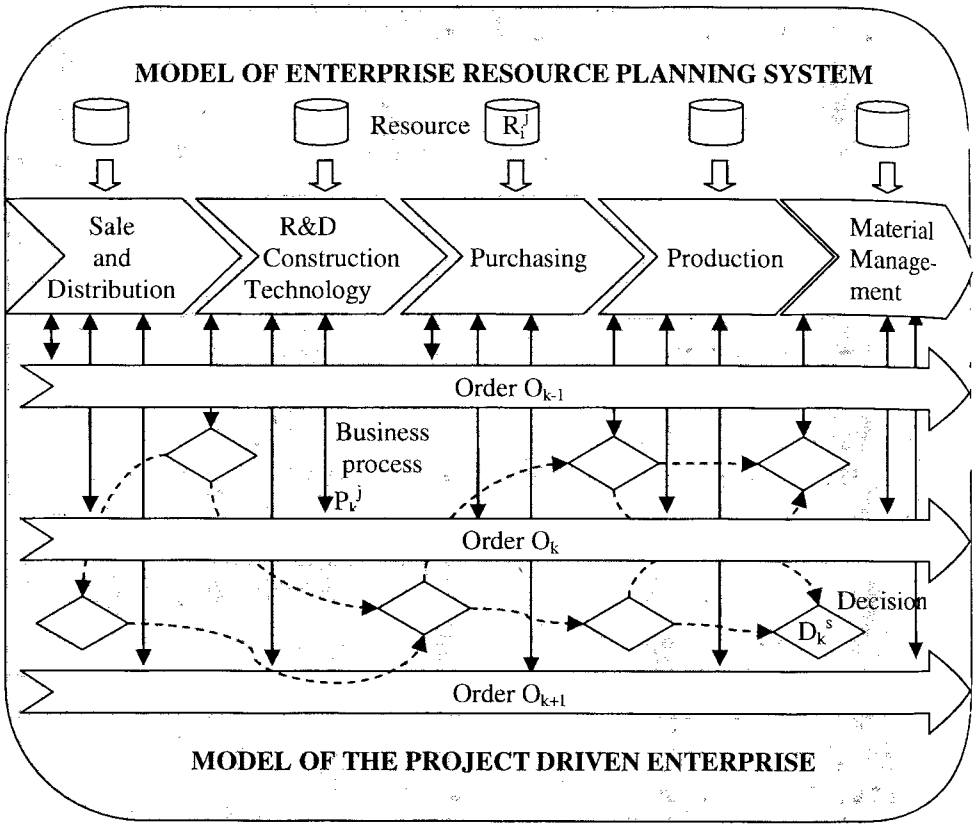


Fig.1 Illustration of the problem statement

The set of adaptation procedures should be constructed on the base of selected parameters to achieve business goals of the enterprise that decide to implement of ERP system. In the next chapters the models of enterprise and ERP system will be presented. The general problem of the paper can be formulated as follows:

*Given is a model of project driven enterprise that include structure of business processes, resources, set of decisions and projects designated for realization by the enterprise. Given is a reference model of ERP system that includes set of functions, and required business data. How construct the procedures of adaptation of an ERP system in the enterprise that guarantee achieving of business goals.*

In the next chapters the model of the project driven enterprise and referent model of ERP system are presented respectively.

## 2. THE MODEL OF PROJECT DRIVEN ENTERPRISE

Enterprise Modeling (ELM), is the art of externalizing enterprise knowledge which adds value to the enterprise or needs to be shared. It consists in making models of the structure, behavior and organization of the enterprise [13]. To understand how an enterprise (or part of the enterprise) really works a model of business processes is required. The model is abstract representation of reality therefore the modelers have to decide on what and how to model. Enterprise modeling requires both a common modeling language and a methodology. There are some languages for business process modeling. The well-known methods for visual modeling of business processes are Integration Definition Language (IDEF) and Unified Modeling Language (UML). CIMOSA (CIM Open System Architecture) provides guidelines, architecture, and an advanced modeling language for enterprise modeling covering function, information, resource, and organization aspects of the enterprise. CIMOSA work has been the root for two European pre-norms produced by CEN TC 310/WGI: ENV 40003 (Framework for Enterprise Modeling), and ENV 14204 (Constructs for Enterprise Modeling) [3]. Some of the methods are implemented in software tools such as ARIS, FirstSTEP, iGrafx, MS Visio, Rational Rose. The mentioned methods and tools enable to describe graphically the business processes and sometimes simulate of the flow of business processes. Unfortunately the quantitative analyze of structure of business processes in view of economical ratios of the whole enterprise is not possible. The proposed model of enterprise is based algebraic described structure of resources and business processes. The flow of each business process can be analyzed in regard of productivity, ratability, performance, costs and other economical ratios. The model of whole enterprise includes the structure of business processes assigned to the functional areas.

There are lot o definitions of business processes in the literature [8], but for this paper the definition formulated by Hammer and Champy [4] is used 'A business process is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer. A business process has a goal and is affected by events occurring in the external world or in other processes'.

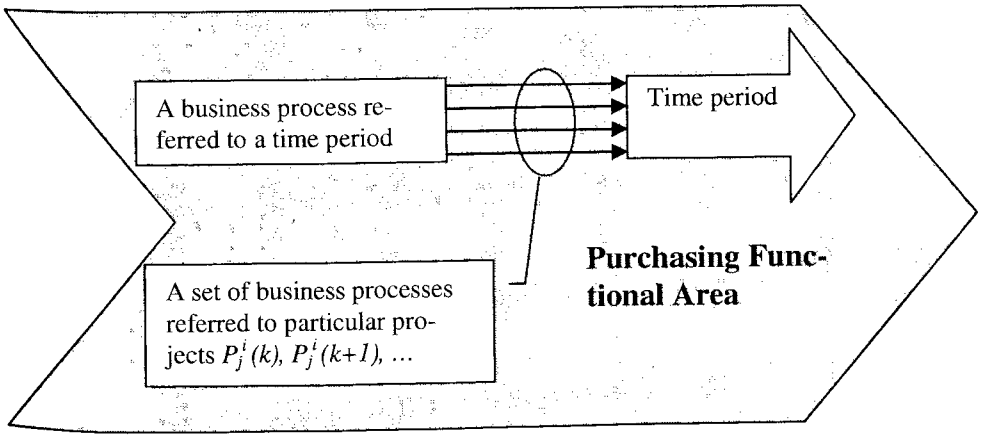


Fig. 2 An example of a business process referred to a time period

Business process is denoted as $P_j^i(k)$ where $k = 1,2,\ldots, Q$ determines an order (project) realized by the process, $i = 1,2, \ldots, N$ determines a number of functional areas that include the process and $j = 1,2,\ldots,M$ determines the number of business processes defined in the functional area $F_i$. Some of business processes can respect more then one order. For example the business process of materials purchasing often is referred to a time period that include a set of orders (projects) and not to a particular project (the notions project and order are used in this paper convertibly). But in the case the business process can be divided on several parallel virtual business processes (see the Fig. 2.1). A typical example of a business process referred to a time period is generating of material list from Material Requirement Planning procedure. Each business processes performed in the functional areas of an enterprise realize partially orders $O_1, O_2, \ldots, O_Q$. For example typical business process $P_j^i(k)$ performed in Sale and Distribution area, concerned with preparation an offer for a customer should perform the following tasks:

- Specification of the customer requirements – project score.
- Calculation of the project – project budget.
- Evaluation of the project labour intensity – project schedule.
- Preparation of the draft contract.

To perform the business processes the following resources are required: salesman, designer, material and labour data, computer, office software. The resources are assigned to a functional area $F_i$ and denoted as $R^i_1, R^i_2,\ldots,R^i_P$ where P is the greatest number of kind of resources in the functional area. The vector $\mathbf{R^i}$ determine the available quantity of each kind of resource in the functional area $F_i$. Each business process consumes the resources during a project realization. For example the salesman consume the working hours. A resource utilization vector $\mathbf{U}^{ij}(\mathbf{k})$ determine the quantity of resources necessary to the flow of $P_j^i(k)$ process and service process vector $\mathbf{H}^{ij}(\mathbf{k})$ determine the time of the resources utilization. For non-renewable resources the elements of the vector $\mathbf{H}^{ij}(\mathbf{k})$ are equal to 1.

An order (project) $O_k$ performed in the project driven enterprise is determined as follows:

1. The time of the project $T_k=(t_k^E - t_k^S)$ where, $t_k^S$ – the term of start, and $t_k^E$- the term of end of the project. Each order $O_k$ is divided on tasks $s_1^k, s_2^k, \ldots, s_n^k$ realized in functional areas for example: $s_i^k=[P^i_1(k), P^i_2(k), P^i_4(k)]$.
2. The total costs of the project $C_k$.
3. The income of the project $I_k$ (the contract price).
4. The score of the project that determine quantity and kind of resources required for the project completion. The score is determined by a matrix of resource demand $S_k$.

$$\mathbf{S}_k = \begin{bmatrix} S_1^1 & S_2^1 & \ldots & S_p^1 \\ S_1^2 & S_2^2 & \ldots & S_p^2 \\ \ldots & \ldots & \ldots & \ldots \\ S_1^n & S_2^n & \ldots & S_p^n \end{bmatrix}$$

If any resource is used by completion of the project $O_k$ then $S^i_j = R^i_j$ in other case $S^i_j = 0$. The costs of the resource utilization are determined by a discrete function of the $F(R^i_j,t)$.

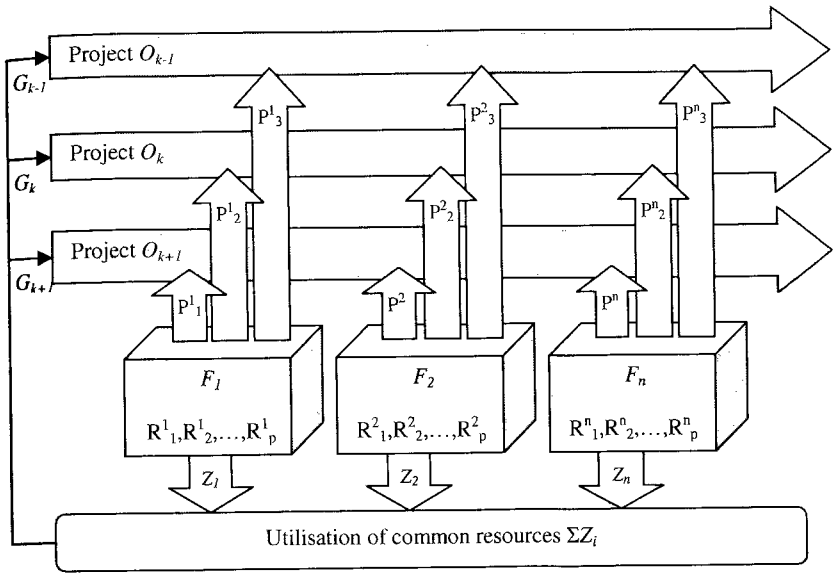


Fig. 3 A project driven enterprise

In each functional area some resources can be assigned that are used for the whole enterprise requirements $Z_1$, $Z_2$, ...,$Z_r$ (for example resources used for marketing, research or accounting). The shares of the resources $G_1$, $G_2$, ...,$G_N$ should be calculated on the base of well-known calculation methods such us ABC method - Activity Based Costing. The costs of resource utilization by a business process $P_j^i(k)$ can be calculated as:

$$\kappa(P_j^i(k)) = \sum_l U_l^{ij}(k) \cdot H_l^{ij}(k) \cdot F(R_l^j, t)$$

To adapt an ERP system for the enterprise requirements a model of decisions that should be supported has to be defined. The evaluation of the ERP system for the enterprise requirements the productivity ratio of the whole enterprise is proposed:

$$P = \frac{\sum_{k=1}^{N} I_k}{\sum_{k=1}^{N}\left[\sum_{j=1}^{p}\sum_{i=1}^{n} S_j^i(k) \cdot F(R_j^i, T_k) + G_k\right]}$$

Another ratio that should be taken into account is productivity of a project:

$$P_k = \frac{I_k}{\sum_{j=1}^{p}\sum_{i=1}^{n} S_j^i(k) \cdot F(R_j^i, T_k) + G_k}$$

In this paper operating decision are taken into account that are undertaken in functional areas of the company. The decisions assigned to functional areas are determined by a vector of decision:

$\mathbf{D^i} = [D^i_1, D^i_2, \ldots, D^i_K]$ where K is the dimension of the vector of functional area $F_i$.

Each decision requires on the input a set of data and on the output a set of business processes that are changed by the decision. Despite of this to the each decision a weight is assigned that determines the importance of the decision. It means that a decision can be defined as

$$D^i_j = (\mathbf{Y}^i_j, \mathbf{P}^i_j, W^i_j)$$

where $\mathbf{Y}^i_j$ – is a set of data required for decision making, $\mathbf{P}^i_j$ is a set of business processes required for decision making and $W^i_j$ is weight of the decision. On the base of the decision model in the next chapter adaptation procedures of ERP system to the enterprise model will be presented.

## 3. THE MODEL OF ERP SYSTEM AND THE ADAPTATION PROCEDURE

There are a lot of ERP systems on the market such as SAP/R3, IFS, MFG/PRO, Oracle E-Business Suite, iSCALA, PeopleSoft EnterpriseOne, AXAPTA, etc. The systems are based on the MRP II method and it enable to build a general model of ERP system. To implement an ERP system in a company the basic data should be stored in the database of the system, the flow of business processes has to be properly adapted to the ERP functionality (or functionality of ERP should be adapted to the company) and the employers should be instructed. The ERP systems are oft offered as a set of integrated modules (Material management, Logistics, Sell and distribution, etc.). The modules of ERP systems can be related to the functional areas of the enterprise. Each module requires an introduction of basic data (for example material indexes, material prices, bill of material, operation times, business partners, etc.) Some of the data is storage in one module, but is used in other modules. The level of adaptation of business processes in ERP system can be evaluated on the base of decision set that can be supported by the system. Let us consider the following decision that should be undertaken in Sales and distribution area:

The income of a project $O_k$ (a production line) is calculated as $I_k$=100 000EUR. Customer can accept the two following variants:

- the price $I'_k$=80 000EUR by the standard guarantee time 1 year or
- the price $I_k$=100 000EUR but with guarantee 3 years.

How can the ERP system support the decision? The decision is concerned with the business process of offer preparation. To support the decision the following function should be performed:

- a calculation of the project (estimated profit),
- a calculation of maintenance costs,
- a calculation of costs of replacements,
- a evaluation of failure risk on the base of resource reliability.

It means that to support the selected decision the set of function should be provided by the ERP system and to perform the functions, the set of data should be given. The functions implemented in the ERP system determine if some decisions of the project driven enterprise can be supported, and the set of required data. Hence, a model of the ERP system is consist of modules that cover functional areas, functions belongs to the modules and data necessary to perform the functions. The procedure of ERP adaptation for the project driven enterprise is presented in the Fig. 4

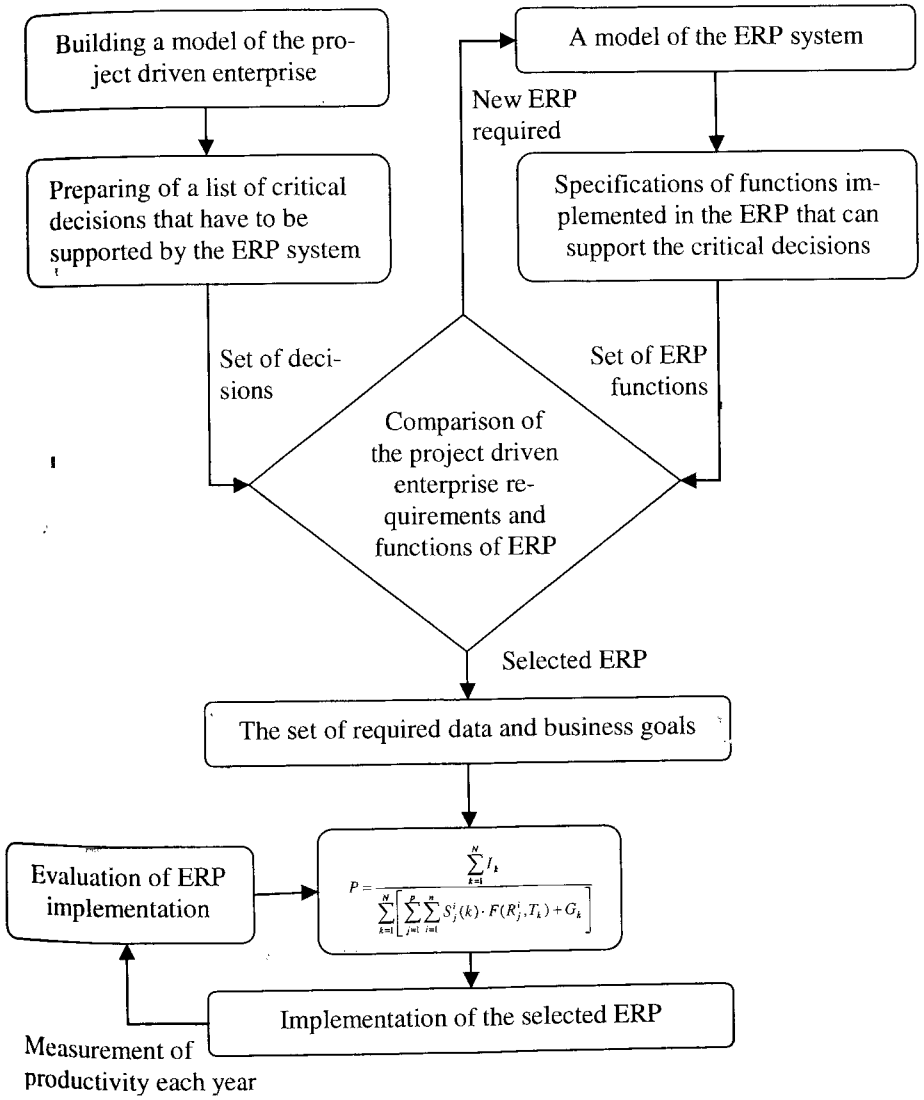


Fig. 4 The procedure of ERP adaptation for the project driven enterprise

The procedure ERP system adaptation compares the decisions from the model of project driven enterprise with the functions from the model of ERP system. If not enough number of decisions can be supported by the ERP a new system should be taken into account. If the model of ERP is acceptable the set of data and business goals can be determined. For the goals evaluation ratios should be calculated as metrics of property implementation of ERP. After the implementation the evaluation ratios should be again calculated to evaluate the results of implementation of ERP. The influence of ERP on the productivity of the enterprise can be measured each year.

## 4. CONCLUSIONS

In this paper a model of project driven enterprise dedicated for improving implementation of ERP system is presented. The model include a structure of business processes, orders (projects) performed by the system and decisions allocated to the functional areas of the enterprise. The model of ERP is consists with functions that support decisions and data that should be introduced during implementation. On the base of the model of project driven enterprise, the productivity ratios have been proposed to evaluate the influence of implementation of ERP in the enterprise. The adaptation procedure described in this paper compare the most important decisions which are undertaken in functional area of the project driven enterprise with functions of ERP. The ERP system that supports the selected decisions and realize business goals of the company should be implemented. The presented models and procedure are a part of a concept of decision support system dedicated for selection and implementation of ERP system in project driven enterprise.

## References


[1] AL-MASHARI M., AL-MUDIMIGH A., ZAIRI M., Erp: A taxonomy of critical factors, European Journal of Operational Research, 2003, Vol. 146, pp. 352-364,

[2] EHIE I., MADSEN M., Identifying critical issues in ERP implementation, Computers in Industry, Vol. 56, 2005, 545–557,

[3] GULLA A., BRASETHVIK T., A model-driven ERP environment with search facilities Data & Knowledge Engineering, 2002, Vol. 42, pp. 327–341

[4] M. HAMMER, J. CHAMPY, Re-engineering the Corporation; A Manifesto for Business Revolution, Harper Business, New York,1993.

[5] HONG K., KIM Y., The critical success factors for ERP implementation: an organizational fit perspective, 2002, Information and Management, Vol. 40, pp. 25-40,

[6] KŁOS S., BASL J., Wariantowanie realizacji zleceń w warunkach ograniczeń zasobowych, Komputerowo zintegrowane zarządzanie. T.1. - Warszawa, Wydawnictwo Naukowo-Techniczne, 2003, pp. 538-545,

[7] KŁOS S., JAKUBOWSKI J., SKOŁUD B., Visualizing business processes in a manufacturing company, Machine Engineering, 2004, Vol. 4, no 1-2, pp. 289-295,

[8] DAVENPORT T., Process Innovation, Harvard Business School Press, 1993, Cambridge,

[9] LEVI M., KLAPSIS M., FirstSTEP process modeler - a CIMOSA-compliant modeling tool, Computers in Industry, Vol. 40, 1999, pp. 267–277
[10] Lindsay A., Downs D., Lunn K., Business processes—attempts to find a definition, Information and Software Technology, Vol. 45, Elsevier 2003, pp. 1015–1019.
[11] MABERT V., SONI A., VENKATARAMANAN M, Enterprise Resource Planning: Managing the implementation process, European Journal of Operational Research, 2003, Vol. 146, pp. 302-314,
[12] MABERT V., SONI A., VENKATARAMANAN M. The impact of organization size on ERP implementations in the US manufacturing sector, European Journal of Operational Research, 2003, Vol. 146, pp. 302–314,
[13] MOTWANI J., SUBRAMANIAN R, GOPALAKRIS P., Critical factors for successful ERP implementation: Exploratory findings from four case studies, Computers in Industry, 2005, Vol. 56, pp. 529–544,
[14] WIE CH., WANG M. J., A comprehensive framework for selecting an ERP system, International Journal of Project Management, 2004, Vol. 22, pp. 161–169
[15] VERNADAT F.B., Enterprise modeling and integration (emi): Current status and research perspectives Annual Reviews in Control, Vol. 26, 2002, pp. 15-25.