advanced planning and scheduling, enterprise resource planning systems

Paweł KUŻDOWICZ*

PRODUCTION PROCESS REAL-TIME OPTIMIZATION BASED ON PROALPHA® APS SOLUTION

Abstract

The issues regarding systems providing an overall view of the work orders to be manufactured and their demand-oriented and on-schedule finishing are considered. As an example the proALPHA® system that provides an overview for the work orders as well as for the available resource and capacities is presented. The system gives the planner all the options for the control. The presented solution shows the user where corresponding bottlenecks occur and puts the planner in a position to counteract accordingly.

1. INTRODUCION

Advanced Planning and Scheduling (APS) has been a buzz word in the ERP scene for about five years. Production planning departments have worked according to the same MRP philosophies for the past thirty years. Everyone agrees these are no longer adequate for today's business environment. Increased demand for customization and shorter lead times are conflicting goals to reducing inventory and optimizing capacity utilization. Systemic restraints prevent optimal planning. Almost all production manufacturers see the problems of production planning. There are cures available for some individual symptoms, but existing approaches can not offer a comprehensive solution [1].

Most of ERP systems available on the market at present fulfil their basic task of optimization of resources utilization in the company (only) within scope. The task of APS module (Advanced Planning & Scheduling) of proALPHA® system, owing to its functionality, is filling this space and brings about conditions for real optimization of resources utilization. This is the next example of change the paradigm in planning for production in the company [7].

The traditional ERP systems base on MRP planning philosophy – in some cases enriched with so-called dispatch stand (Germ. *Leitstand*). Figure 1 illustrates comparison classic approach to the planning according to MRP used by most of ERP systems and APS conception realized in proALPHA® system. The main difference consists in resigning from time-consuming sequential planning for material requirement and also manufacture resources load in favor of simultaneous planning for many resources and optimization of their utilization according to company economic goals.

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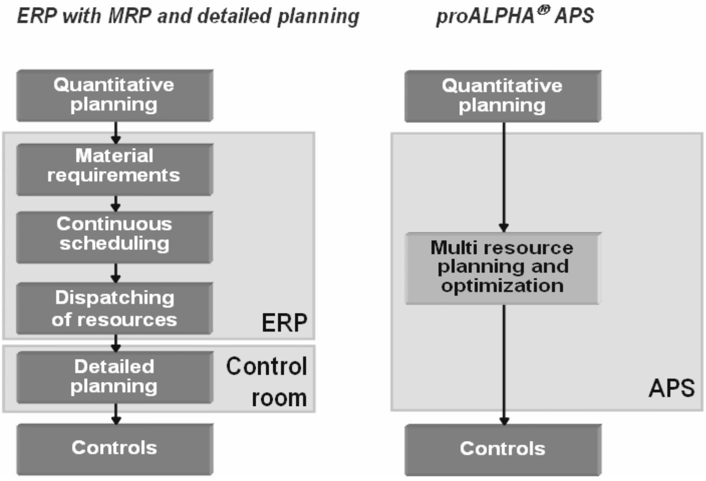

Fig. 1. Comparison of MRP and proALPHA® APS (based on [4])

2. THE SYNCHRONIZATION OF RESOURCES AVAILABILITY

One of the conditions to achieve realistic results of planning is simultaneously taking into consideration all essential resources. Only when all resources availability is guarantied, it is possible to start to carry out definite operation. This means necessity of synchronization of terms of supply with materials with rest of resources availability, e.g. workers, machines, tools and instrumentation of the machines or assembly area.

Fig. 2 illustrates the example the synchronization of two resources availability: of the machine and the tool in the context of settlement of material requirement. Part a) presents classic approach to the planning for material demand, that provides the of delivery time (RLT) settled

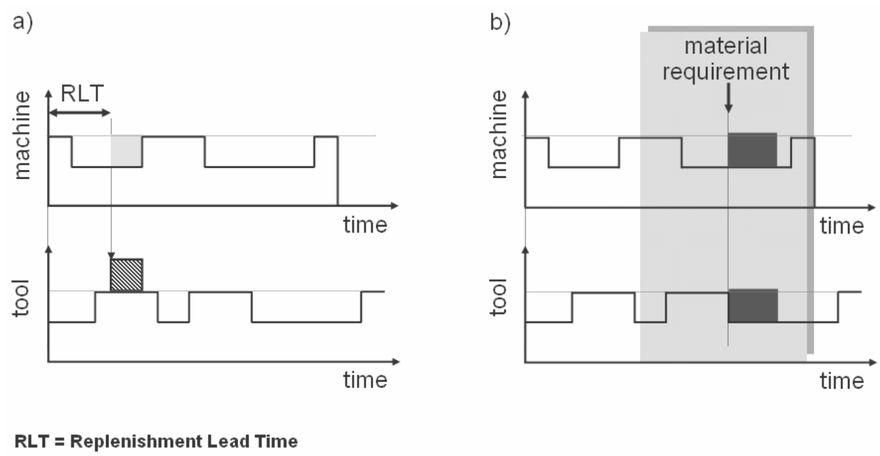

Fig.2. The synchronization of resources availability (based on [7])

only on the base of one resource availability – in this case it is the machine. The resource in the form of the tool unavailability is not taken into consideration. Therefore the delivery of the material in fixed time does not allow starting the manufacturing process, because the tool resource is unavailable. Part b) presents the determination the material requirement procedure, which takes into consideration rest of resources availability. Therefore the synchronization of all resources availability causes determination more real term of starting realization of manufacturing process. In this case, considering appropriately later machine and tool availability, the delivery date of the material will be late, what will cause limitation of excessive warehouse stocks.

The additional advantage of resources synchronization in planning is shortening so-called lead time of manufacturing process. Figure 3 illustrates example of three alternative realization of work order composed of three operations realized suitably on resources 1, 2 and 3. The classic approach (variant 0) considering lack of resource synchronization, assumes forming fixed queue times among particular operations. This example presents situation that even the application of above mentioned fixed queue time does not guarantee order realization on time. This refers in particular to the operation 2, that in terms of considering unavailability of resource 2 in expected time - will really undergo displacement. It can cause possible extend of the lead time.

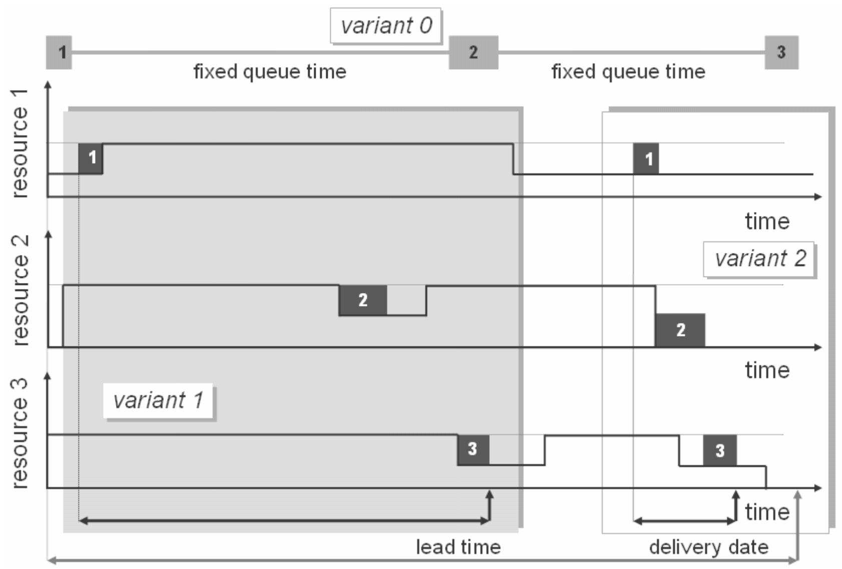

Fig. 3. Lead time as planning result (based on [7])

The multi-resource planning connected with synchronization of resources does not require forming above mentioned fixed queue times. It allows consider possibility of realization of many variants in particular. The example illustrates two variants (1 and 2) and each of them characterizes shorter lead time in comparison with initial variant (0).

In proALPHA® solution many resources can be theoretically assigned to the given operation, what allows to see the manufacturing process conformable to the reality. During defining the process can be consider [7]: attendance many machines, superposition of working operation and also forming and partial batches transfer.

3. PRODUCTION PROCESS REAL-TIME OPTIMIZATION

The optimization of resources utilization proceeds considering minimization of delays in realizations of order, minimization of accelerations, minimization of order lead time an also minimization of resources standing time. Importance with reference to particular goals can be bestowed individually, for example depending on line or considering individual requirements of particular parts of company (in case of multi-factory companies, for example – of given factory). Except for general goals whole company keeping the terms of deliveries of particular orders or resources utilization can have different importance. It is possible by the bestowing individual importance on concrete order or resource.

The following example illustrates the function of optimization in proALPHA in a simple way [5]: A work order is planned for the parts A, B and C each. Each work order has three operations that are processed at different work stations (machines). Each work station (machine) has a capacity of 8 hours per day. Each operation, on the other hand, requires 8 hours. Planning the work orders in the sequence "Part A", "Part B" and "Part C" results in the following resource utilization. Hence, part A ends on day 3, part B and part C on day 4 (see table 1).

Tab. 1. Planning the work orders without optimizing

	Day 1	Day 2	Day 3	Day 4	Day 5
Machine 1	Part A	Part B			
Machine 2		Part C			
Machine 3		Part A	Part B		
Machine 4			Part C		
Machine 5			Part A	Part C	
Machine 6				Part B	

Optimizing the three work orders results in the table 2. Now, part B and part C end on day 3, while part A ends on day 4. What happened? Since the work orders have the same priorities and requested dates, two work orders end on the requested date (day 3). With optimization, two instead of one work order can be delivered on schedule. The priority for "Part A" can subsequently be increased. The higher priority in the delay results once again in the representation shown in the first image, i.e. the work order is complete again on day 3.

Tab. 2. Planning the work orders with optimizing

	Day 1	Day 2	Day 3	Day 4	Day 5
Machine 1	Part B	Part A			
Machine 2	Part C				
Machine 3		Part B	Part A		
Machine 4		Part C			
Machine 5			Part C	Part A	
Machine 6			Part B		

APS is much more than just elaborate planning. APS influences other functions within the business, like material management and order entry and how purchasing acquires parts. It is not possible to see APS as a separate module. Planning algorithms have consequences for other modules and, in the end, affect the goals of the entire company. Goals and objectives may be defined that restrict use of resources. Depending on the specific conditions, run times and delivery schedules can be planned to optimize the downtimes of individual machines. All of these improvements are made possible by the loose linkage of product to process structure. It is not optimization of single process steps but the optimum cooperation of the entire production process including all resources and all production steps [1].

4. CTP REQUEST

More often in companies exists necessity of quick confirmation order's date realization. In particular in production for client's order, where there are not margins of safety of finished goods and there are complex structures of products, there is a need of confirmation of delivery date in real time considering actual resources accessible. This kind of feasibility checking is defining like a date demand (capable to promise, CTP). Classic ERP systems do not offer within this range of function possible to the practical use. The process of CTP demand is presented on Fig. 4.

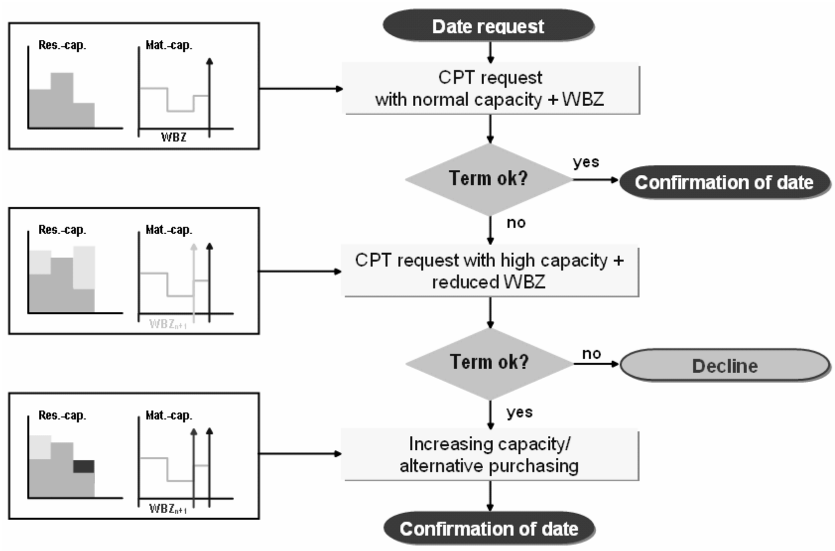

Fig. 4. CTP request based on proALPHA® APS(based on [4])

If the first request does not give satisfactory result, there is a possibility of planning using resources overload or/and shorter time of new material purchase. The resources overload is leveled by adaptation of production capacity (for example, by overtime). The shorter time of new material purchase means for example using alternative suppliers.

APS plans completely. Existing systems, including Manufacturing Execution Systems (MES), define routings to manufacture a component as a pre-defined sequence of operations. With

APS we will be looking at order networks. The process of manufacturing a component does not have to be a sequence. APS uses the concept of multi-resource planning. That is, all the resources needed for the production of all orders over the entire planning horizon are taken into account. The different planning phases of MRP and MES are performed in one single planning step.

This sounds simple and logical but requires a complex and combined planning. All resources like employees, machines, tools, materials and transport equipment involved in one order within the planning horizon have to be assigned to that order and considered when planning all the steps of another order that is competing for the same resources. This results in a considerable decrease in "priority" orders. Even rush orders are processed in the normal production cycle without the panic [1].

5. THE ADVANTAGES OF IMPLEMENTATION

So far the implementations of APS functionality have been done in a wide circle of companies, employing from one hundred to one thousand employees. These are companies belong to such trades as engineering industry, equipment's and tools' production, electric industry, automotive industry, with type of unitary, serial and mass production. These experiences prove first of all that following advantages of APS application have been gained [7]:

- plans possible to realization (simultaneous consideration of many resources);
- intentional influence delivery on term, reserves, resources utilization (optimization);
- quick confirmation of delivery date, greater competitive, reduction of planning costs (possibility of planning ad hoc, CTP);
- high flexibility, planning close to the reality, complete approach (structures oriented on the process);
- high transparency, shortening of delivery times, keeping the terms (consideration whole chain of value formation).

The above-mentioned advantages can be practically gained only in fully integrated solutions. The considering solution, except full integration of all functional areas: sale, purchase, production, material management and finances, is equipped in addition in OLAP tool to multivariate analysis ad hoc - proALPHA® Analyzer. It is useful for resources utilization analysis in particular (workstation, man, machine, tool) with division on days, weeks and also months (Fig. 5).

The achievement of goals assumed during APS implementation requires many organizational and systemic changes in the company. To the organizational changes can include adaptation structure of data, business processes and very company organization. Particularly important is the improvement the quality of data collected in system, beginning from the e.g. time of new purchase, planning material parameters, being up-to-date of registered work orders status (arrears), as well as communication between departments during realization individual business processes. The system changes means first of all rising of qualifications (substantial, cultural) of management and employees and also enlargement of hardware medium and software (additional server optimization, components for visualization, communicational software).

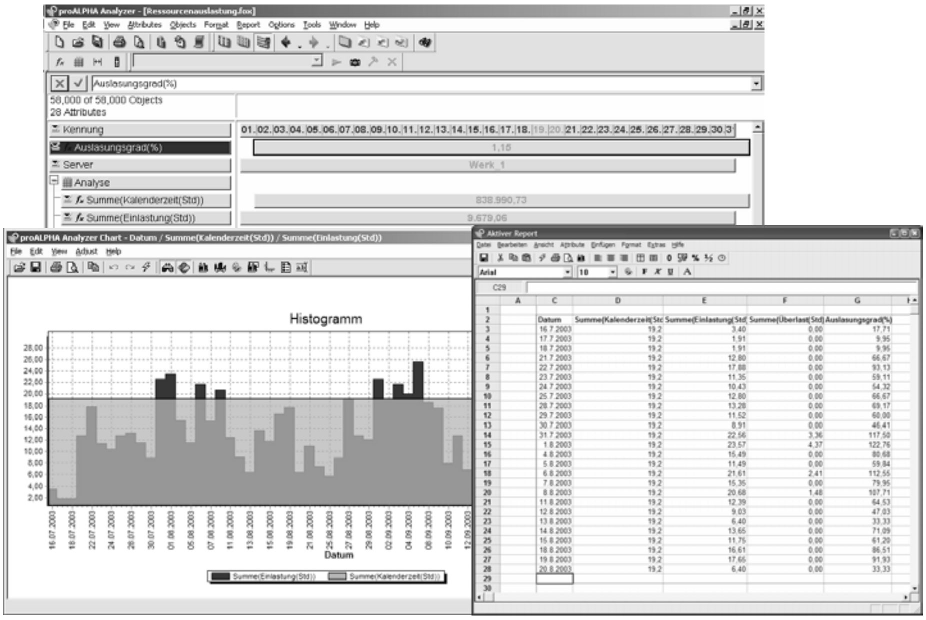

Fig. 5. Resources management with the aid of proALPHA® Analyzer (based on [4])

6. SUMMARY

In many manufacturing companies, it is possible that employees have no overall view of the work orders to be manufactured and their demand-oriented and on-schedule finishing. For this reason, a system providing such overview is necessary. proALPHA® is an example of solution which gives a system that provides an overview for the work orders as well as for the available resource and capacities. In the process, it gives the planner all the options for the control. The presented solution shows the user where corresponding bottlenecks occur and puts the planner in a position to counteract accordingly.

The advantages resulting from the use of the analyzed solution exist on condition of solving problems connected with the acceptance of results by users and also with data quality.

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engineering design, fuzzy sets, uncertainty

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CHOSEN PROBLEMS OF MODELLING ENGINEERING DESIGN PROCESS

Abstract

An overview of the various models for engineering design process was presented. General Design Theory, Basic Model, Real Design Model were described. Type-2 fuzzy sets implementation on engineering design process was described.

1. INTRODUCTION

Product development and design are directly connected with the enterprise strategy and the marketing research results. The designer is to create new products or to modify the old ones according to the marketing department's demand. The product must fulfil the requested technical parameters, but also the demands concerning the economical production, quality and reliability [14].

A company, to be competitive must continuously improve its products and processes. The development of company can be realized using its own human potential, or using transfer of technique. The transfer of technique can be realized using formal or informal methods (Fig. 1). The formal methods are for example: purchase of licence, patents, use of consulting firm. The informal methods are: exchange of technical staff, conferences, trade, exhibition, professional training.

An example of the direction of research and development work was presented on Fig. 2.
Design process is a halfway between research process and routine organization procedure of production preparation.

Development and research work is connected with uncertainty and risk. Risk is connected with internal and external factors. Internal factors include: human mistakes, information computing mistakes, machine failure. The external factors include change of law, atmospheric conditions.(Fig. 3).
The goal of the article is to create mathematical framework for modeling by words engineering design process.

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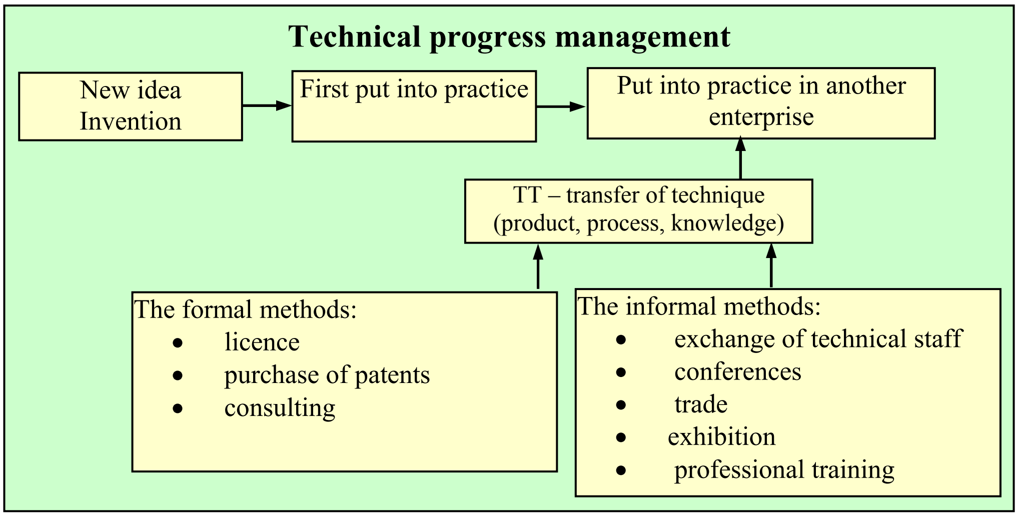

Fig. 1. Technical progress management

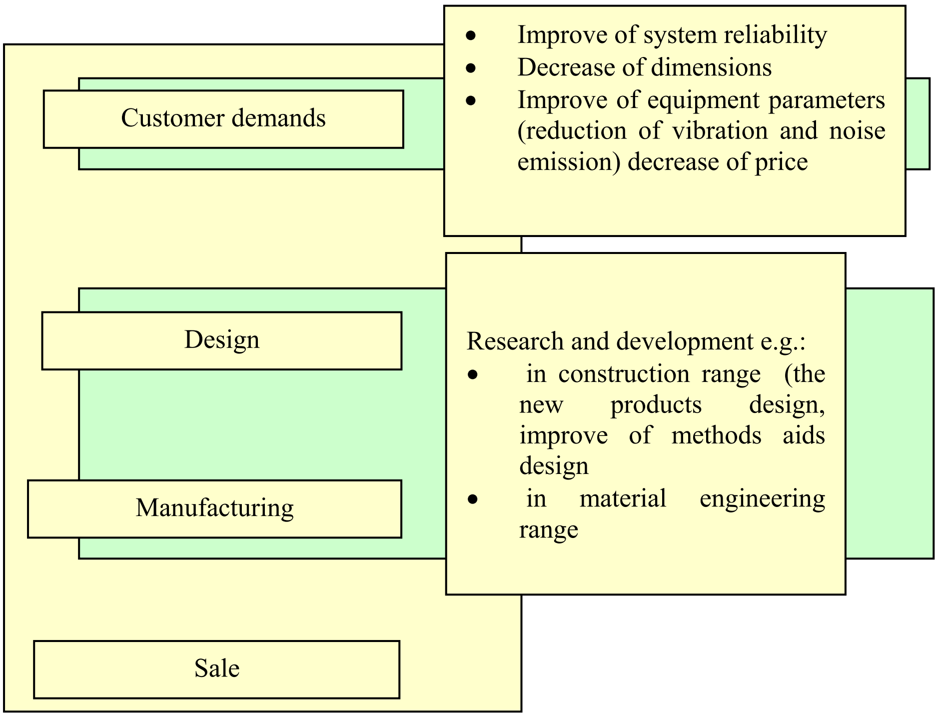

Fig. 2. Research and development trends

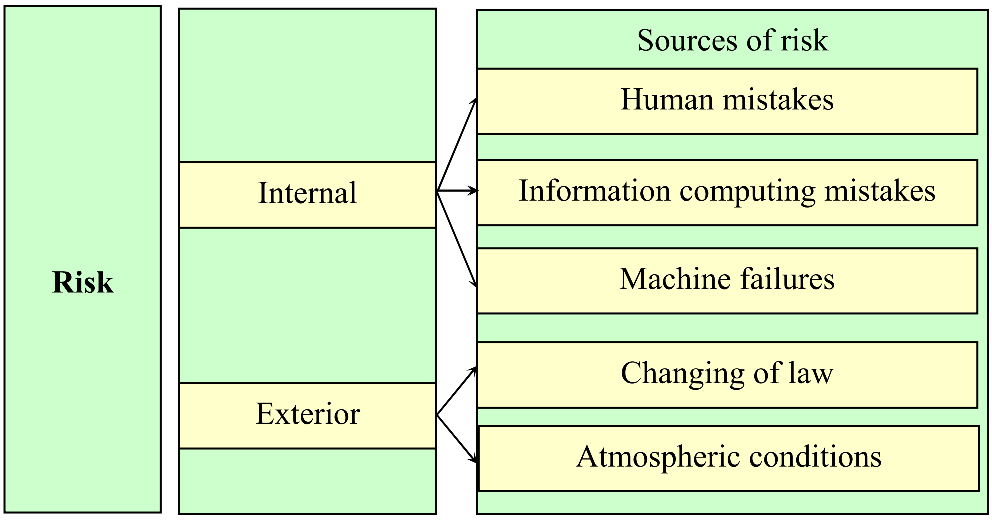

Fig. 3. Source of risk

2. REVIEW OF CHOSEN MODELS FOR ENGINEERING DESIGN PROCESS

Mathematical formalisms of design have been of great interest to many researchers over the years [16], [5], [6], [4], [9], [13]. General Design Theory formulated by Yoshikawa [20] is a well known one. General theory of design is based on topological model of human intelligence. Topological models use for modelling objects description definition, axiom and theorem. This approach is based on the idea that design is set of entities and consequent definitions. From that definition it is possible to state axioms [16]. The following three axioms are presented in GDT as the basic properties of these concepts: axiom of recognition (any entity can be recognized or described by the attributes), axiom of correspondence (the entity set S' and the set of concept of entity S [15] have one to one correspondence), axiom of operation (the set of abstract concept[16] is a topology of the set of entity concept[17]).

In GDT, there are two kinds of knowledge for design: the ideal knowledge and the real knowledge. The three axioms are valid only on the ideal knowledge. The ideal knowledge is represented by two topological spaces: the functional and the attribute space and a map between these topologies. Design is basically an activity, which connects design specification (denoted by functional concept set) and design solution (denoted by attribute set) [13].

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[15] The entity set S is e set which includes all entities in it as elements. By all entities, we mean entities which existed in the past, are existing presently and will exist in future. This set is denoted by S'[9].
[16] The set of abstract concepts is derived by the classification of concepts of entity according to the meaning or the value of entity [9].
[17] Concept of entity is concept which one has formed according to the actual experience of an entity [9]

Design solution is obtained immediately after the specification is described without design process in the ideal knowledge. Design is not necessary under the ideal knowledge. This situation is called by Kikichi i Nagasaka [9] a paradox of GDT.

Braha and Reich [4] based on [1], [2], [3], [7], [19] developed basic model for design process. The basic model formulates design as a process that starts from abstract specification such as customer needs or functional requirements in the function space. The designer matches partial structural information in the structural space, with the current refined specification [4]. The process continues until the solution is obtained.(f_i is the current tentative specification list and f_{i+1} is a proximal refined specification list). A design process is obtained by selecting at each refinement stage a single generating element out of many possible ones. The basic model has many limitations and some aspects of real design do not captured by the model, i.e. multifold mappings between the functional and structure space, feedback loops. Because of those limitation Braha and Reich [4] developed more realistic model called real design model. This model captures the interplay between design descriptions, each of which is represented by a pair of functional and structural descriptions <f,d> [4]. The designer starts with the initial design description <fo, do> (fo - means initial specification, do - means initial context descriptions). During creation of a new design description both functional fi and structural di description can be refined (Fig. 4).

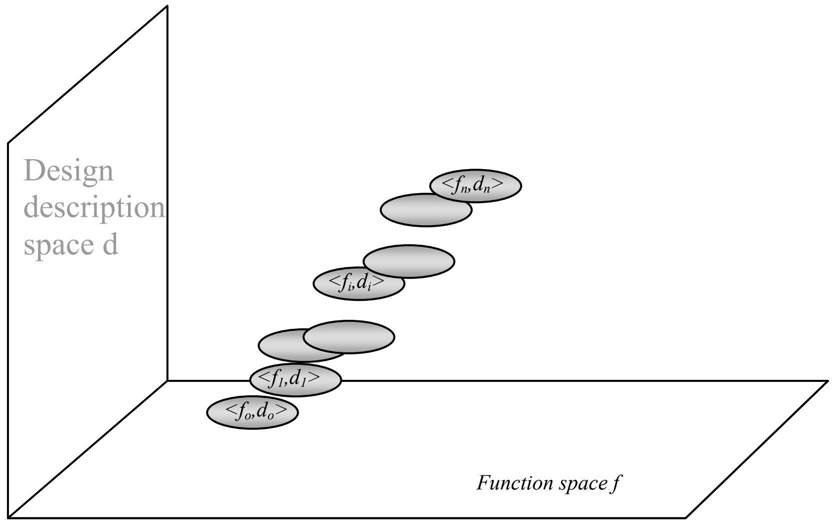

Fig. 4. Design process (developed based on [4])

3. APPLICATION OF ARTIFICIAL NEURAL NETWORK FOR DETERMINATION TIME CONSUMPTION IN DESIGN

Design process required more detailed analysis of process then it was described in previous part of the article.

Methods described above are connected with topological structures for engineering process design. The design process is connected with time and labour consumption (Fig. 5). Next part of article describes how to determine time consumption of design process.

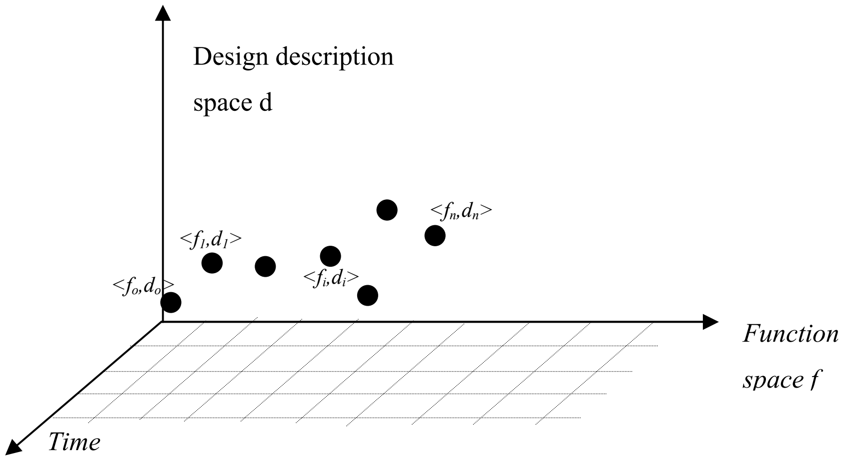

Fig. 5. Design process

We can received the time consumption data using neural network.

Artificial neural network are electrical analogue of the biological neurons system. A typical artificial neuron is mathematically represented by two modules: a linear activation and non-linearity that limits the signal levels within a finite band. Neurons in an artificial neural net are connected in different topological configuration. Two most common type of configurations are feed-forward and feedback topology. Usually, a feed-forward network contains a number of layers, each layer consisting of a number of neurons. Signal propagation in such networks usually take place in the forward direction only, signals from the I-th layer can be propagated to any layer following the – th layer, for i ≥ 1. In the recurrent neural network, there exists feedback from one or more neurons to other.

Informally "encoding" or "learning" refers to adaptation of weights in a neural net. Thus until the weights converge to a steady state value, the process of encoding is continued. Adaptation of weights can be accomplished in a neural net by for different ways:

- supervised learning – employs a trainer, who provides the input-output training instances of given neural net.
- unsupervised learning – unlike supervised learning, an unsupervised learning requires no teacher. Consequently, there is no target outputs. During the training phase, the neural net categorizes the received input patterns into different classes.
- competitive learning – competitive learning process are usually represented as artificial neural systems with self-existing recurrent connections.
- reinforcement learning – weights are reinforced for properly performed actions and penalized for poorly performed actions.

There are about 30 different NN architectures, which are being employed in research at present (Suthomaya, Tannock, 2005). Each NN architecture and training algorithm combination is suitable for different situation, depending on what kind of work the network is expected to do. The network adopted in the case study below was the multi-layered perceptron (Fig.6).

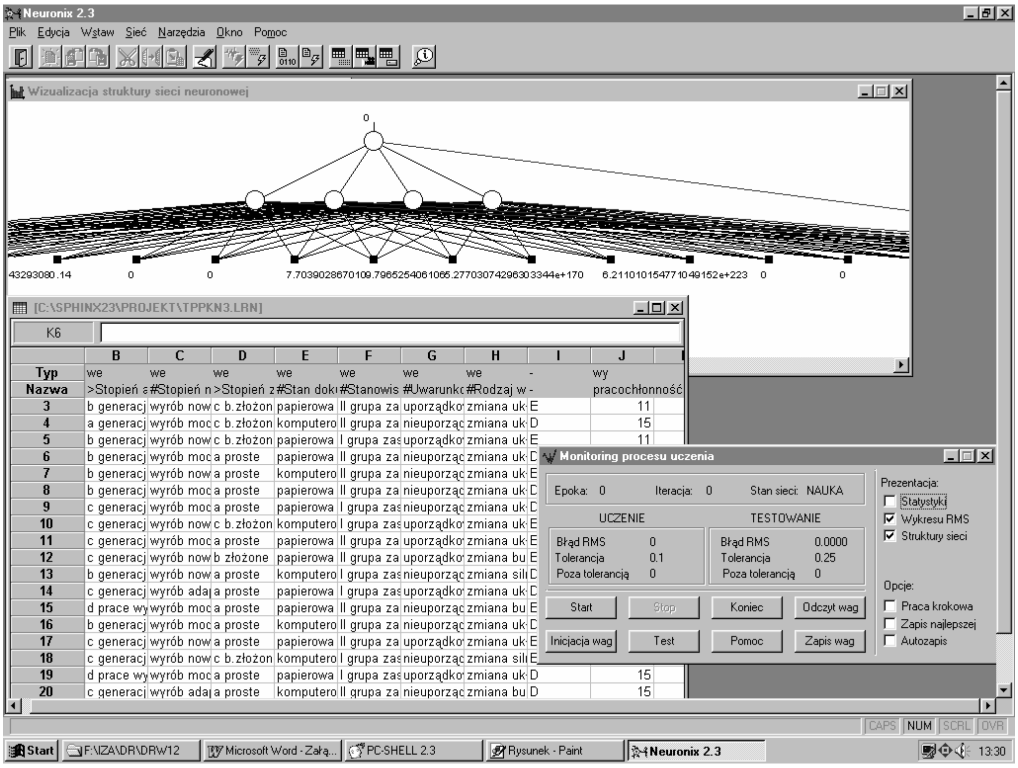

Fig. 6. Neural network

The SPHINX packet including NEURONIX module, which is the simulator of the neural network, was used in the example.

4. IMPLEMENTATION FUZZY SETS IN ENGINEERING DESIGN PROCESS

Fuzzy sets have been around for nearly 40 years and have found many applications [11].

Membership functions of type-1 fuzzy sets are two-dimensional, whereas membership functions of type-2 fuzzy sets are three-dimensional. A type-2 fuzzy set provides additional degrees of freedom that make it possible to directly model uncertainties.

A type-2 fuzzy set [10] is characterized by a type-2 membership function $\mu_A(x,u)$ where $x \in X$ and $u \in J_x \subseteq [0,1]$.

$$A = \{((x,u), \mu_A(x,u)) \,|\, \forall x \in X, \forall u \in J_x \subseteq [0,1]\} \quad (1)$$

where $0 < \mu_A(x,u) < 1$.

In real design it is necessary to distinguish intermediate stages which are required to make the decision whether to continue the design process or not.

Engineering design process requires dividing analysis into stages. After each stage the probability of continuing the design process is going to be analysed. It will be analysed linguistically - in words. For modelling this process fuzzy set type II can be used. (Fig. 7).

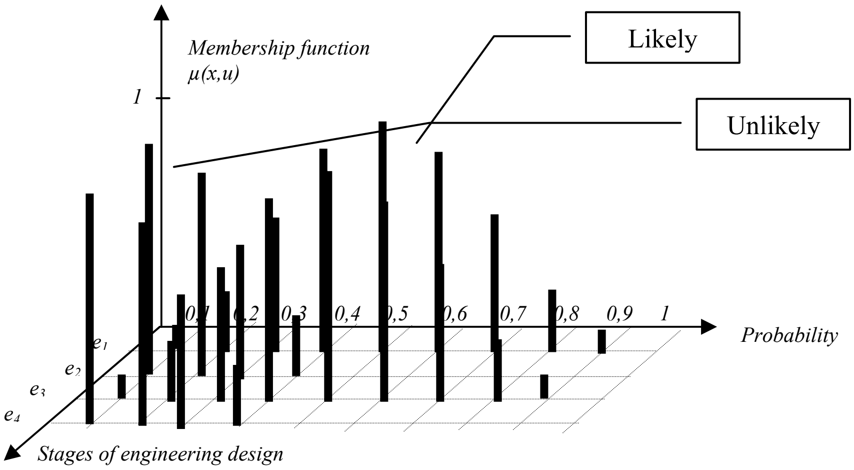

Fig. 7. Example of a type-2 membership function

4. CONCLUSION

Development and research work is connected with uncertainty and risk. Many models for engineering design process are described in literature but it is necessary develop a new one which uncertainty involved. A new methodology should base on linguistic variable. That methodology should give answer for following questions: how long the design process to stay and haw mach it will cost? And also it should help in optimization of design process. In those article was presented chosen tools like neural network and fuzzy sets, which can be used for develop e new method of modeling engineering design process.

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cooperation in production, outsourcing, computer aiding

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SYSTEM OF COOPERATION DESIGN

Abstract:

The problem of system aiding of inter-enterprise cooperation process designing is presented in the article. Development of enterprises' productivity requires making the start, creation, and extending of cooperative links among enterprises easier. Development of methods and ways of data exchange in cooperation enables creation of aiding computer systems of production cooperation.

1. CONDITIONINGS OF PRODUCTION COOPERATION

1.1. Tendencies in production

Production enterprises are forced to search for ways of increased productivity and decreasing the cost of production, as well as introducing even shorter cycles of development for products and processes of their production by means of minimization of the stock and well organized logistics, and thanks to effective and innovative realization concepts In production, such as: LP (Lean Production) – rational production, JIT (Just in Time) controlling supply according to the principle just in time, TQM (Total Quality Management) -, VF (Virtual Factory) - (understood as temporary network of co operational links of different enterprises with a common aim of realizing a production task).

Next conditionings of production include globalization of links in production. It is accompanied by virtualization of link organization. Cooperational outsourcing relates to the effective methods of designing, production, using and maintaining of one's products; here both the environment of one's enterprise and the external environment of competitive companies are taken into account.

Externalization as a kind of enterprises' strategy

Externalization- outsourcing- is a way of strategic action which means sending production processes and sub-processes including manufacturing of sub-assemblies by sub- suppliers, maintenance processes and failure repairing, storing, logistics, buildings security, computer service, researches, training, providing services etc. outside the enterprise. If an enterprise renounces one part of added value, then mark-up, flexibility, concentration of attention, and financial outlays on the processes, which provide competitive advantage, will increase.

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1.2. The phenomenon of synergy in cooperation

Many enterprises create such value of cooperation which enables them to gain bigger effects of synergy. The phenomenon of synergy, known in the past well, means “a state where the whole is bigger than the total sum of its elements” [5]. The base for synergy is creative role of a human which can be seen in looking for optimal combination of elements of organizational processes.

A synergic effect as an outcome of cooperation of many factors:

- Appears in an organized structure (e.g. in an enterprise, in workers’ teams),
- Appears in rational undertakings and complex structures and in processes taking place in them,
- Is an indicator of the influence and mutual conditionings of elements of complex tasks,
- Is qualified and evaluated by means of physical, economic or agreed criteria of evaluation,
- constitutes a linking effect and may be separated into the effects of organizational components.

The main area where synergy effect appears is organizational structure and its rules of cooperation by labor division in the organization.

1.3. Structure in production cooperation

Enterprises in a global market function in a very differentiated and dispersed organizational structure, and their production is an outcome of tight cooperation with many cooperators.

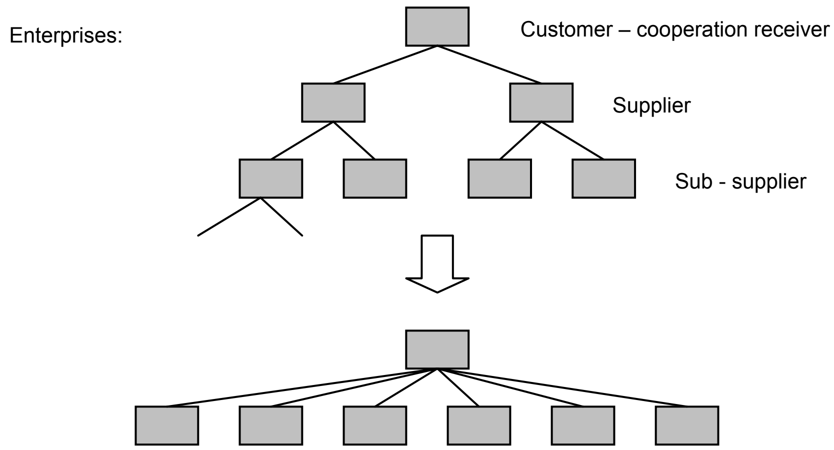

Fig. 1. Changes in co-operational structures of the production process – flattening of the hierarchy of links between enterprises

The changes which are taking place make it necessary to create a new model of organization of links between enterprises working together, especially functioning on the global market. Changes in the structures of the whole groups of cooperating enterprises undergo the same tendencies as enterprises themselves – it is presented on Fig. 1 and 2.

The BASIC features of changes in the model of links between enterprises working together are the following:

- ✓ *Flattening of cooperation structures*; the hierarchy of links and stages of cooperation change,
- ✓ *The model of network organization* – still new, faster and more often made alliances and strategic relations through borders of countries, industries, markets and zones of activities. Global companies are constantly looking for new constellations and alliances in their search for taking control over markets or gaining access to resources (including supply, sub-contractors etc.).
- ✓ *Making smaller the organizational entities,* which create the network, and focus only core competencies which give in a given configuration competitive advantage. All activities of operation and activities which may be performed better and cheaper wherever in the world are "pushed out" of the organization – externalization (outsourcing).

Openness of an organization – activities open for new ideas for products and ways of working, open for information from outsider, actively scanning the surrounding looking for "weak signals" which are a sign of unknown threats and opportunities, open for information created within the organization.

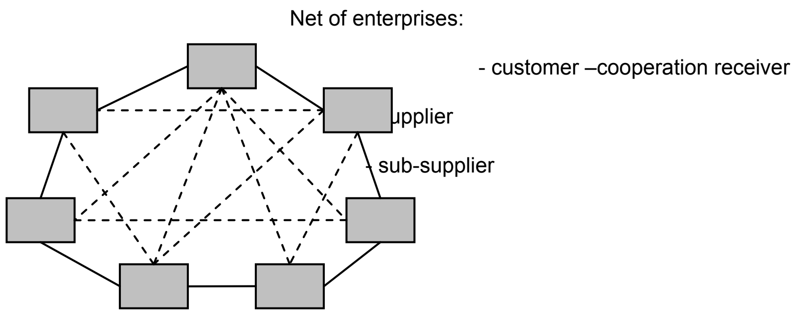

Fig. 2. Networks in co operational structures of the production process

The conditionings of enterprises working together cause that their structures are built horizontally around the processes, whose "owners" are complexes of various composition and quite amorphic structure – organizations described as modular are created– Fig.3. within the enterprises themselves is creates [2]:

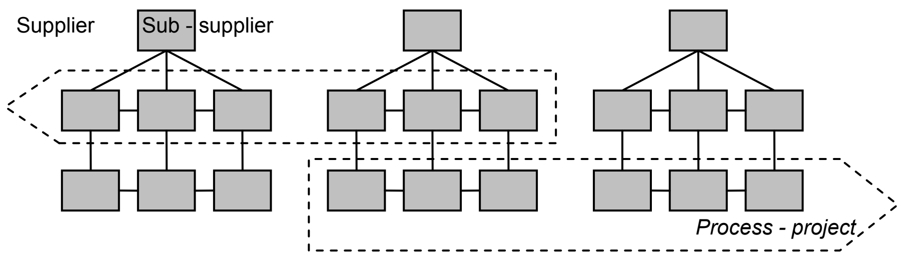

Fig. 3. Modular organizations in co operational structures of the production process

- a requirement of multi-task attitude and principally changes a contract between the employer and the employee;
- that there is a lack of guarantee for employment on a particular position for a longer period of time;
- that workers become ‘nomads wandering around networks of linked organizations’ [2], increasing their skills and offering their higher qualifications to constantly changing teams;
- that it is more and more difficult for exempt oneself from the compulsion of enterprise in relation to oneself;
- that the place of climbing the hierarchy ladder is replaced by a number of short, ‘flat’ careers.

A model of functioning of computer integrated co operational enterprise is created (see Fig. 4), which is structurally similar to the newest form of organization aiming at creation of functionally dispersed enterprises, also called virtual enterprises [8].

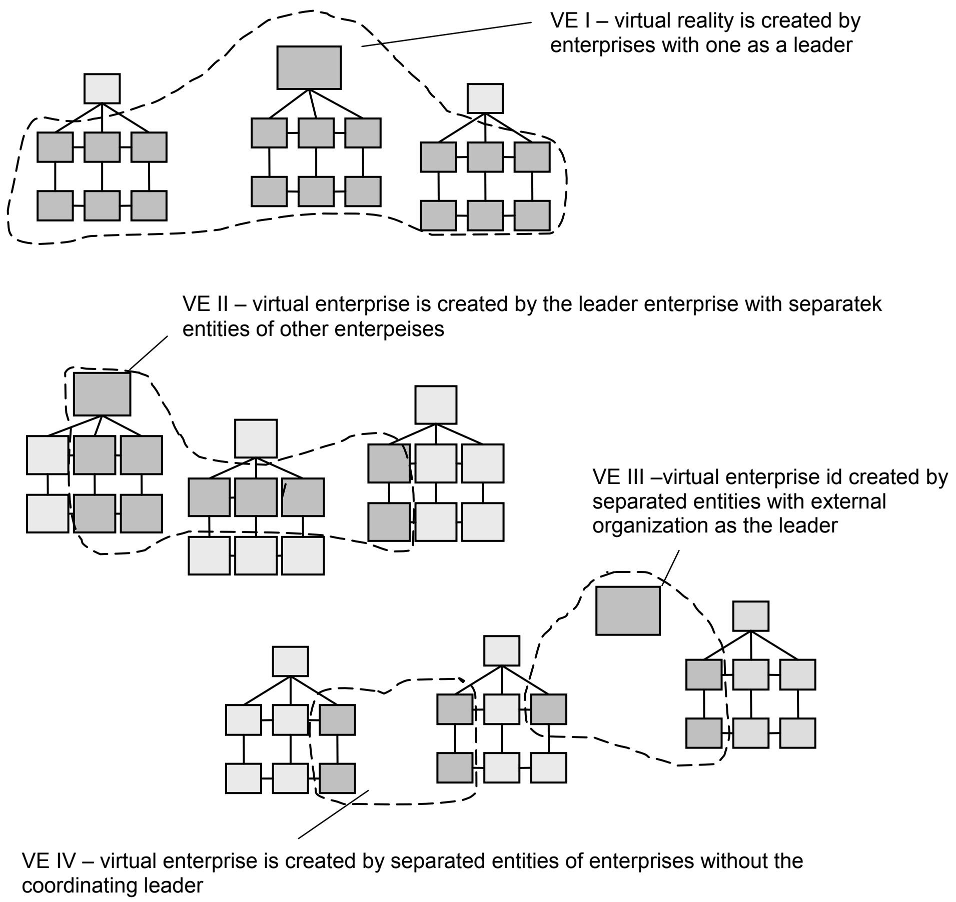

Fig. 4. Virtual enterprise in different sample kinds of structures

A model of functioning of computer integrated cooperative enterprise, which would be similar to the most modern organizational form, is being created. This modern form is to create functionally spread enterprises called virtual enterprises [3]. In the article there are accepted the facts that the organization in voluntarily created and its members are connected with one another in many ways for the sake of the realization of a mutual aim [2,3]. Membership in the organization does not require any civil - law agreements. The time of the relationship is established by each member.

1.3. Computer environment of cooperation process

Organization of cooperation run is strictly connected with computer technology which is used in the enterprise. The complex computer systems in enterprises, which are being developed currently, are systems of ERP class (Enterprise Resource Planning) defined as sets of strongly integrated software packages which can offer coherent information flow in the enterprise. In the area of production there work CAD, PDM, CAM, DNC systems which are integrated with them. Other systems are the ones which work in the Internet environment and other tele-computer nets like WAN. Easy access to the Net resulted in B2C trade with mass customer systems development (Business to Customer) and systems which aid B2B inter-enterprises (Business to Business).

The next systems, which are being developed nowadays, are the systems of Supply Chain Management (SCM) and of Customer Relationship Management (CRM). These systems integrate the activities among business partners on the strategic, tactic and operational levels and function in integrated chains within the frames of one enterprise on the account of lack of adaptation to changes in chains consisting of independent partners.

2. DESIGNING MODEL OF PRODUCTION COOPERATION PROCESS

2.1. Exchange of data by cooperation

Tendencies of development of global enterprises, of creating new cooperative links are visible also in the dynamism of the need to exchange information – cooperative data. The number of linked subjects in production cooperation is growing. Fig. 5 presents data exchange in cooperation with one leading enterprise – the leader. In this situation there is a need to determine the shape of information transmitted in the initial stage of cooperation initiation, which is safe for the know-how of an enterprise.

Different types of norms were created are being implemented, like norms of ISO 9000 series related to quality control, ISO 14000 series related to ecological production and ISO 10303 norm, commonly called the STEP norm (Standard for the Exchange of Product Model Data). This norm standardizes product modelling and design of the processes of its production, with the view of formats of data exchange and integration of multifunctional computer systems, aiding the design and production.

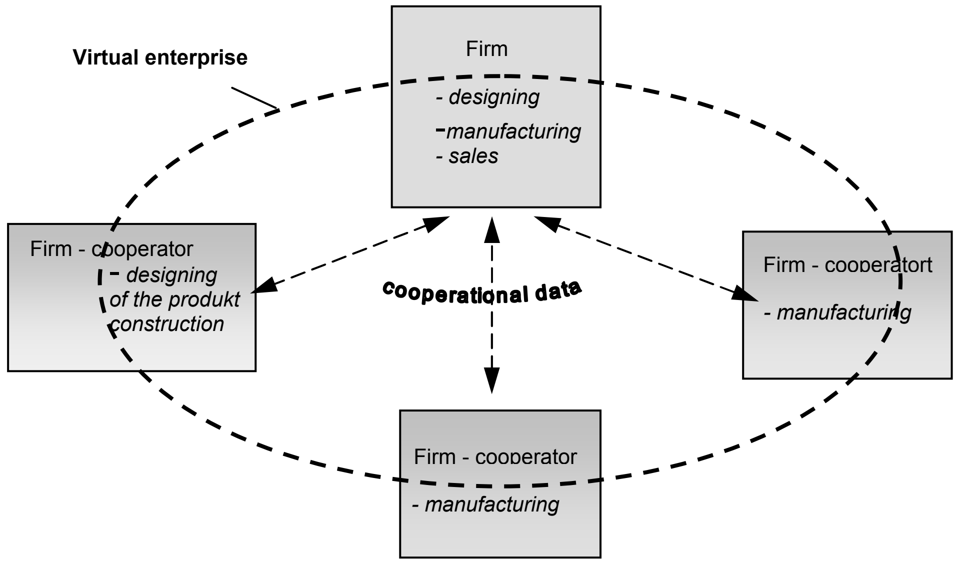

Fig. 5. Data exchange in production process cooperation

In many places works are being carried out on such a standard of product model record, which would include complete data about this product and the process of its production.

It has to be underlined that ISO 10303 - STEP norm is in the initial stage of implementation eden in automobile industry enterprises, where the most modern technologies are introduced.

The STEP standard determines the rules of creation of a product model in a way, which allows for reworking and storing information about a product and the processes of its manufacturing. The product model and data model arising out of it include: [1], [7]:

- information and definitions of description of drawings
- basic data of technical drawings in the form of annotations and attributes, with general information abort a product and adequate descriptions,
- special annotations relating to dimensions, tolerance and measurement units included in the drawing in the form of a complex data model.

Implementation of the STEP standard requires fulfilling a set of conditions:

- using the standard CAx software, allowing for building an open CIM system,
- using models and structures of data based on neutral forms of data record and standard protocols of their transmission,
- aiming at a coherent description of model and structure of a product, allowing for full data exchange in geometric, technological and organizational models.

2.2. General model of production cooperation designing process

Having assumed that the most future promising form of enterprises cooperation is virtual enterprise, the main problem becomes defining of composition and number of cooperating units which are geographically spread. The process of selection of cooperation partners is strictly connected with an order which determines the criteria of selection and analysis process.

Well carried process of selection is the key to match co-operators with such resources, material possibilities, appropriate technologies and well trained staff in the comparison with order-design that can guarantee gaining synergic effect and product's position on the market.
Cooperation designing process in the presented aspect can be viewed in four phases as it is presented in Fig. 6.

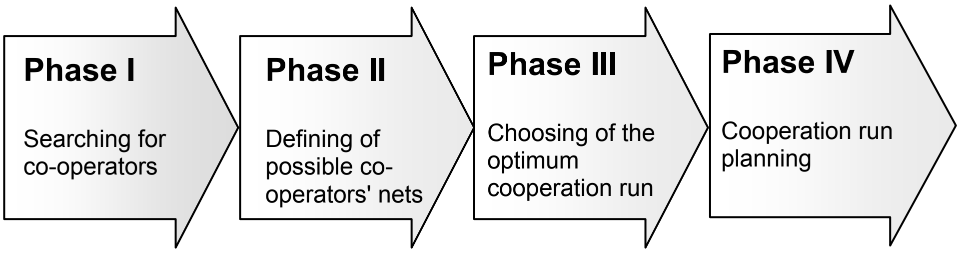

Fig. 6. Phases of designing stage of production process cooperation

The discussed problem of cooperation designing requires production designing and its flow to be broaden through the issue of marking and optimization of organizational structures of labour run for enterprises set. Determining of the optimum production process in cooperation requires multi-criterion marking for the variant of cooperation process- production process route in the subset of enterprises. The result of the issue is regarded as NP problem- difficult, requiring inclining expenditures of calculations in problem size function.
To make the problem more general, it is reduced to certain answers to the given questions:

- do the enterprises which can compete in realization of a certain project exist?,
- which of these enterprises are able to create the nets which would have free resources for order's realization?,
- which of these nets of co-operators are able to create optimum production process?,
- how to organize and control the cooperative run of production in the net?

The solution of the problem will specify which subset of enterprises- corresponding with its PW which abilities guarantee keeping term-price-quality appointments with the client.

2.3. A standard of data exchange in cooperation initiation

Development of cooperation requires data flow according to a standard of data exchange of a product model for cooperation in the moment of its creation. Standardization should include:

- a need of determination the information form in the initial phases of cooperation, secure for the know-how of an enterprise – Fig. 7 - phases I - II - III,
- modelling of a product and processes of its manufacturing, taking into account the formats of data exchange and integration of multi-functional computer systems aiding the production designing – Fig. 6 - phase II.

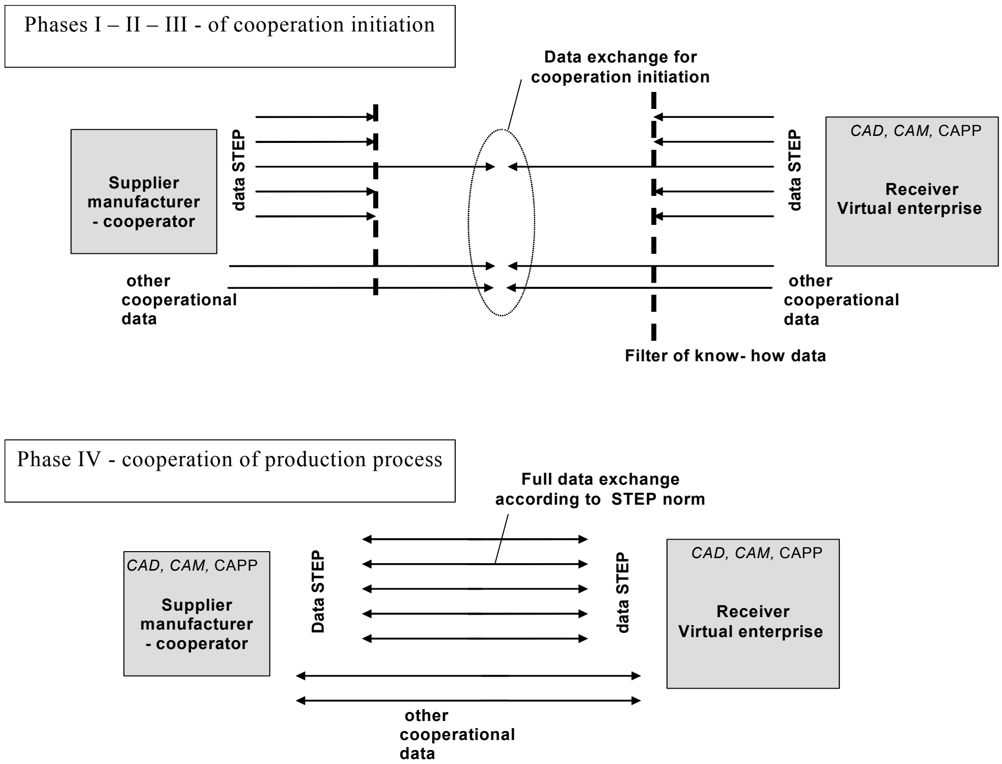

Fig. 7. Flow and standard of data in initiating and carrying out cooperation

The phases I, II and III of cooperation take place the most often in two situations – when an enterprise is looking for an cooperator for:

- new parts of already produced goods,
- new parts of new products.

Phase IV is developed by producers, an example of which is software appearing on the market for modelling and simulation of business processes, and issues of cooperation process management of small companies with firms working on the global market, e.g. the 3CP Programme – a global system of common information accessible for engineers and suppliers of Ford company all over the world. The main element of C3P is a set of tools called FPDS (Ford Product Development System), aiding the planning, designing, development and production processes.

Using the STEP standard in this phase makes it possible to record all data about a product needed in the production process in a normalized form: from the specification of the order, PDM documents flow management, through data from PPC and CAD/CAM systems to feedback information from the production department about the manufacture and usage of a product. Thanks to STEP we obtain a normalized record of geometrical, material, constructional, technological and graphical specification of a product. This record reaches the lowest level of graphic presentation in CAx systems, which means the level of the so called *graphic primitives* [1].

Graphic primitives defined in CAD systems agree with the specification of the *Graphical Kernel System*, which is the basis of programmes for input – *output* handling for systems and graphic devices, the so called *drivers.*
Feature Modelling is a kind of newer, widely used method of modelling usually 3D blocks, which have some specific constructional and technological features. Elementary objects – constructional objects and technological ones with semantic record project the constructional and technological models of a product.

After the first phase the producer transmits data about a product to the potential supplier. Using fully standard recommendations of the STEP norm, implemented in all cooperating CAx systems facilitates the full exchange of data between the producer and the supplier after phase III.
In the designed object we can distinguish three groups of variables X_p:

- -constructional features (Π) – the collection of variables explicitly describing constructions:
  - -geometric features – dimensions and their values, parameters of the shape and location, parameters of surface geometry (within the above notion we distinguish a notion of constructional form – a record of shape without determining the dimensions),
  - material features – sorts and kinds of materials,
  - initial settings, parameters of assembly let-ups, initial tensions,
- (Λ) - minimal collection of variables determining the features of the designed object in respect of the environment, e.g. constructional qualities (durability, effectively, weight, dimensions, dimensions of assembly holes); qualities connected to the manufacturing process (costs of production, labour consumption), usage features (time of reaching, reliability of work, time and frequency of service activities).
- technological variables (Γ) – minimal collection of variables which characterize processes and phenomena taking place in technological processes.

This means respectively:

$$\begin{aligned} &\Pi_k ;\ k = 1, ..., k \\ &\Lambda_w ;\ w = 1, ..., w \\ &\Gamma_s ;\ s = 1, ..., s \end{aligned} \qquad (1)$$

Information transmitted by an enterprise to a supplier in the phase of initiating cooperation constitute data about a product (1) e.g. these are variable Π_k and Λ_w – Fig. 8.

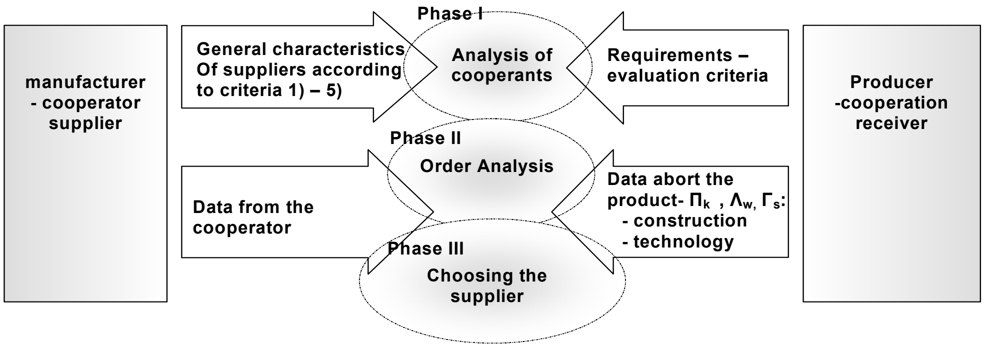

Fig . 8. Data exchange and its analysis by initiating of cooperation

This data is stored in the constructional documentation - the CAD files. The information transmitted to the producer by a potential supplier in the phase of cooperation initiation which chooses the best supplier more detailed data to the former characteristics – answers for questions of criteria of choosing a supplier. These are data about:

1) quality – accuracy, quality systems' certificates,
2) competitiveness – price,
3) innovativeness – used technologies and possibilities,
4) service – time of delivery, long-term cooperation,
5) flexibility – possibility of changing the sizes of deliveries, production capacity.

2.4. Tendencies in production cooperation process designing

Shortening of production process designing thanks to cooperation aiding system together with cooperation process formulating (Simultaneous Engineering – SE) is presented in Fig. 9.

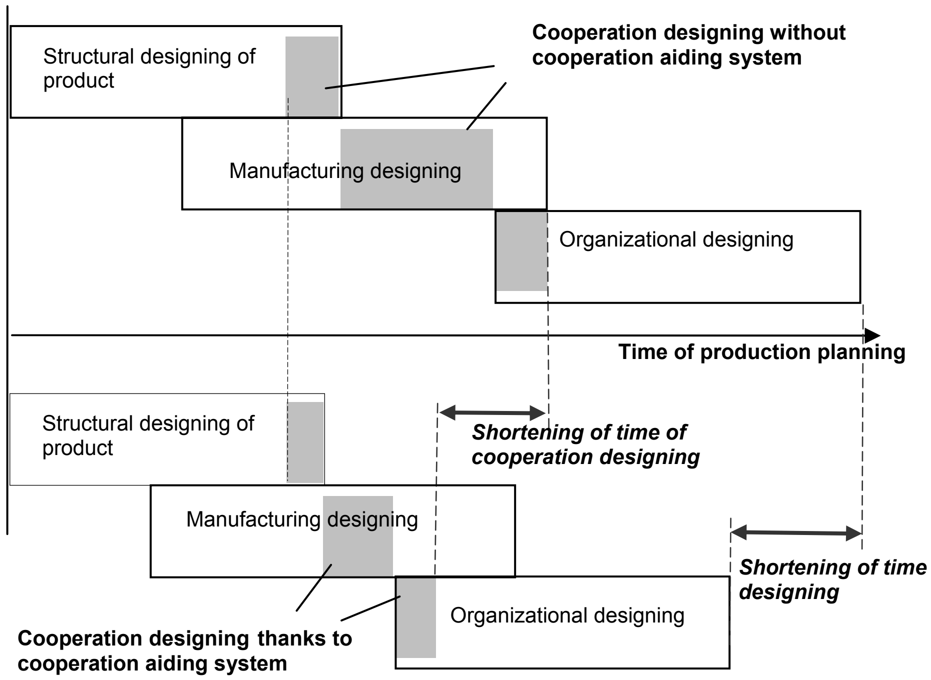

Fig. 9. Application of cooperation aiding system to shorten the time of production designing

As given in pictures 1 and 3 lack of earlier information, reaction to coming information, its receiving, elaboration of the correct answer takes time and as a result the total sum of these delays gives information delays in cooperative production process.

The proposed solutions of this problem allow for putting forward the thesis that the implementation of such changes in organization which can change system's paralysis is necessary. To make the information circulation in cooperative system – customer- producer-supplier faster, usage of database computer system to aid the searching and choosing of cooperator phases is needed.

The proposal of the system which makes information circulation faster is the implementation to the system of additional information which is realized in real time. It makes estimation of system answers and choosing of the co-operator possible.

3. SYSTEM OF COOPERATION DESIGN

3.1. Phase I – looking for co-operators

Data form for cooperation aiding system

Development of cooperation requires data flow according to the elaborated standard of data exchange model of the product for cooperation at the exact time of its coming into being. Standardization should also take the need of information form determination into account, especially in the initial phases of cooperation, which is safe for know-how of the enterprise – phases I-II-III - Fig. 10.

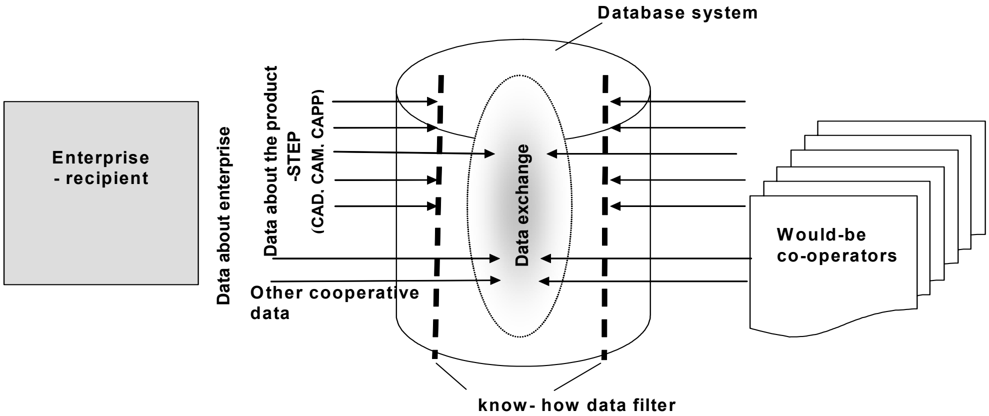

Fig. 10. Cooperation aiding system – cooperation start initiation phase – data standard and flow

The characteristic which describes the potential co-operator is information about the enterprise which is limited by the security of know-how of the enterprise. The fundamental features are needed in this phase are pieces of easy available information about the enterprise:

- information which identifies the enterprise,
- enterprise's products,
- used technologies,
- technological and innovative level,
- broadly described quality - quality certificates,
- production ability- size of resources.

The accepted assumptions concerning the requirements of the designed production specify customer's requirements and define minimal abilities of potential cooperative manufacturing system. Having implemented all the requirements, set by the designed production, the proposed system enables to find enterprises which can take part in production process.

Assumptions of cooperation aiding system

The answer to the question: *Who can cooperate in production order realization?*- requires knowledge about enterprises which exist on the market. Defining of possible co-operators set leads to the conclusion that there is a need to create a database about these enterprises where potential co-operators will be selected – Fig. 11.

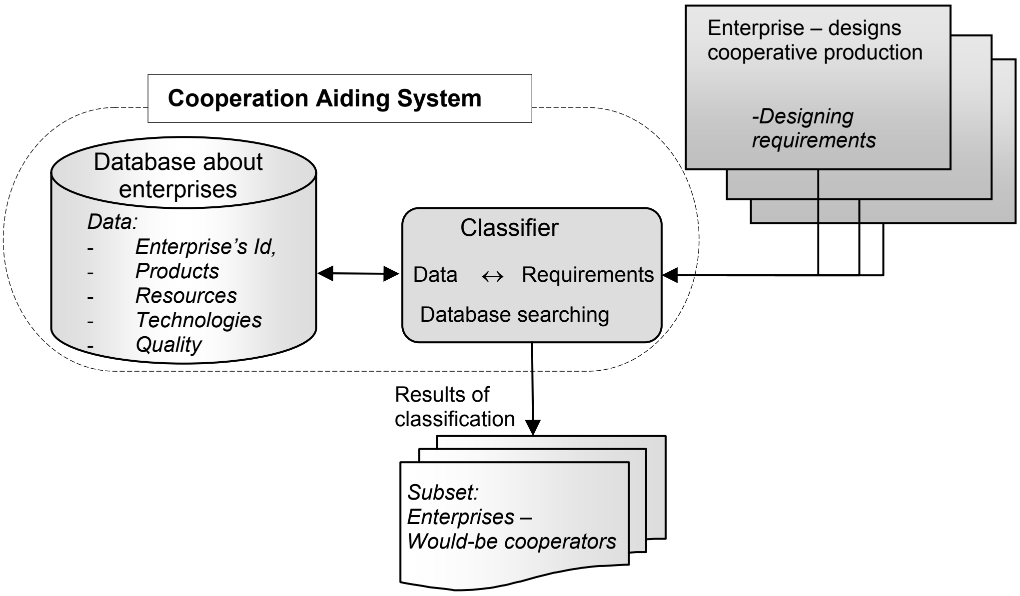

Fig. 11. Searching of would-be cooperators in production

The problem requires supplier- producer model creation which would describe the standard of requirements for the virtual enterprise. The proposed solution is based on creation of a base for enterprises defined with fundamental information needed in this phase of virtual enterprise designing, in combining with the system of base searching by the use of classifier, basing on the criterions which are specified for the designed production.

3.2. Phase II – defining of possible co-operators' nets

Among potential cooperators in the next phase of virtual enterprise (VP) design there exists a need of finding solutions having free resources which would guarantee realization of an order in the assumed time, according to the assumed cost and accepted level of quality. Generally, the problem of resources' engagement can be proved by:

- the applied in practice simple correspondence with an answer about a possibility of order realization – the need to administer specialized technology and resources and with setting price conditions. After this the asked person analyses the order after having prepared and sent back the answer. Then potential variants of nets are created, which are composed of resources of the chosen sub-composition of enterprises. The basic disadvantage of the traditional procedure is high time consumption of the activities;
- using the method based on the computer system of browsing the space of potential solutions, taking into account possibilities of access to production capability

limited in time. The method requires knowledge of the state of resources engagement of potential cooperators in the whole planning period.

The advantage of using the procedures of browsing with computer aid is instant analysis outcome. Using the method of browsing of initial solutions (coming from phase I) consists in balancing the requirements of order realization – the design with possibilities of the analyzed enterprise. What are analyzed are maps of resource accessibility in time in comparison to production specifications of an order – Fig. 12.

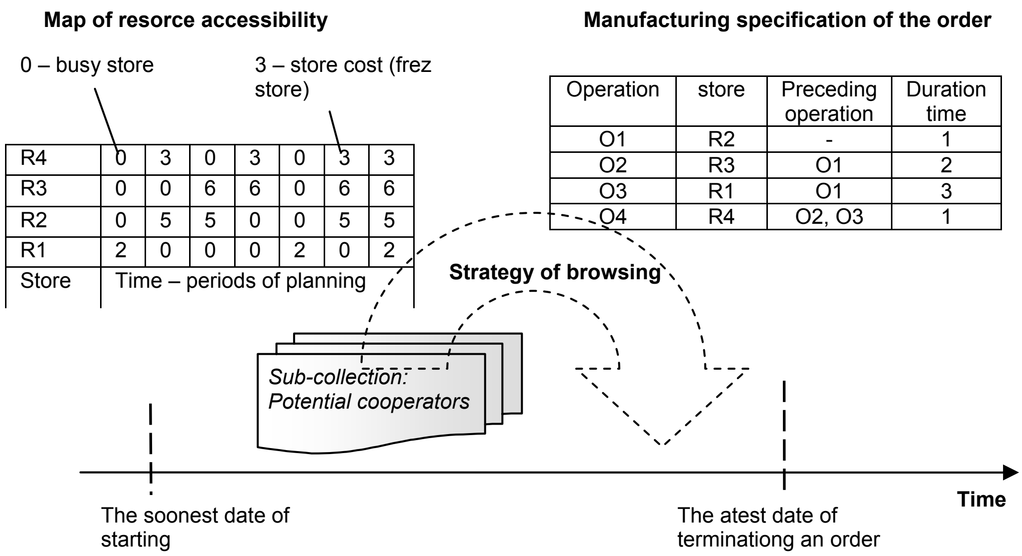

Fig. 12. Searching for possible production schedule in cooperation

A sample method of determination of accepted nets of cooperating enterprises was presented in this work [11], was based on two strategies of heuristic browsing of possible solutions' composition:

- nets with the highest value of top limitation – reserves of time for realising the order,
- nets with the lowest values of top limitation,

The work [11] proposes using of four heuristics of resources' allocation for the order operation:

- the smallest lengths of accessibility time,
- the largest lengths of accessibility time,
- the lowest average costs of resource use,
- the highest average costs of resource use,

The method allows for proposing a solution which would be the most advantageous when it comes to time or cost of order realization. What is left is the problem of the choice of the best one and of defining the notion of the best cooperational solution for the production.

We need such a method which would allow for carrying out a multi-criterion optimization with respect to time, cost and quality of order realization, as well as taking into account the estimated risk of failure to fulfil the requirements by a given variant of the net of cooperating enterprises.

3.3. Phase III – Choice of the optimal cooperation run

The method which links the evaluation with different criteria in one is the analysis of utility of projects of the course of production cooperation process. The evaluation of utility should take place continuously in the course of designing after phase II, which was finalized by setting the nets variants of the course of cooperation process (production process of VE).

In respect to the basic criteria of quality, cost and time, the model of the course net of production process cooperation is subject to the proposed optimization activity, whose structure is described by the graph (Fig. 13):

$$G_N = V_N, L_N \tag{2}$$

where:

$V_N = \{v_i;\ i = 0, 1, ..., N\}$ – collection of summits,

$L_N = \{l_{ij};\ i = 0, 1, ..., N\text{-}1;\ j = 1, 2, ..., N\}$ – collection of graph's arches.

Each summit of the graph may be associated with an event which begins or ends a task of production process cooperation, and the arch represents the task itself.

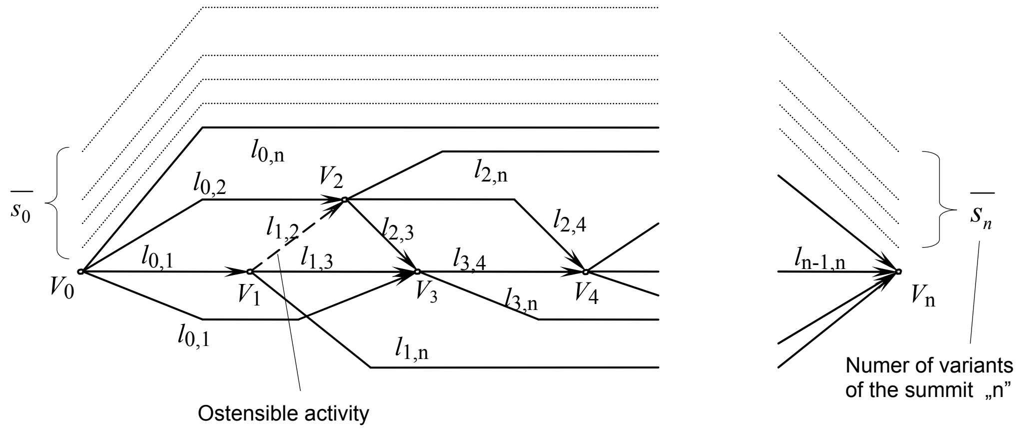

Fig. 13. A graph of the production cooperation process (self elaboration)

The presented organization causes that the graph oriented from the summit "i" to "j" to become a directed graph – a *digraph*. The summits which are not connected with an arch can be linked by a mock activity that is with an arch, for which the describing functions possess zero values. Each task may be attributed with:

- t_{ij} – time of realization of task i, j
- $k_{ij}(t_{ij})$ – function interpreted as the cost of activity realization l_{ij} with time of realization t_{ij}.

Assuming that: $\{0 \le a_{ij} \le t_{ij} \le b_{ij}\}$, where b_{ij} may be called normal time, and a_{ij} - emergency time, which means that realization with shorter time may cause wrong designing of the process. What is more, t_{ij} may take only values of integer numbers.
Each activity is connected with the value q_{ij}, explicitly presenting the gained quality, usually gained accuracy class, the number of shortages and even more parameters – a vector of quality.

Event which begin or end the tasks of production process, which are summits of the graph v_n may be analyzed similarly like in [10] and developing them adequately (according to their numeration) we can attribute them with collections of functions (see Fig. 14):

$$T_{s_n}^{n} = \max\left(T_{s_{n-1}}^{n-1} + t_{n-1,n}, \ldots, T_{s_1}^{1} + t_{1n}, t_{0n}\right) \tag{3}$$

$$Q_{s_n}^{n} = \max\left(Q_{s_{n-1}}^{n-1} + q_{n-1,n}, \ldots, Q_{s_1}^{1} + q_{1n}, q_{0n}\right) \tag{4}$$

$$\mathrm{K}_{s_n}^{n} = \max\left(\mathrm{K}_{s_{n-1}}^{n-1} + k_{n-1,n} + k_{n-2,n} + \ldots + k_{1n}, k_{0n}\right) \tag{5}$$

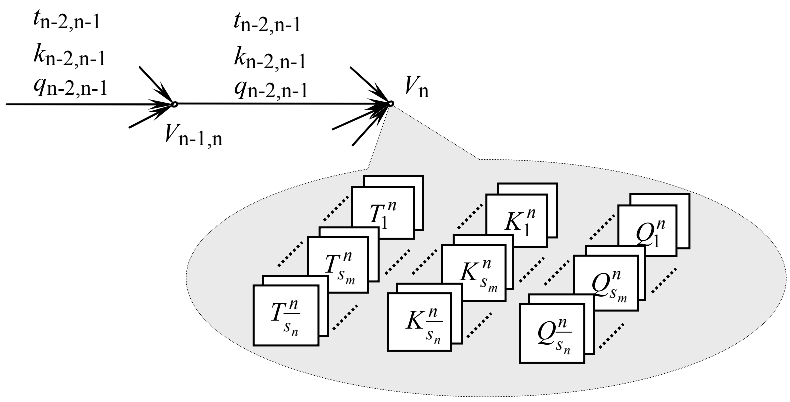

Fig. 14. Functions of the graph summit v_n of the process (self elaboration)

So, the values $T_{s_n}^{n}, Q_{s_n}^{n}, K_{s_n}^{n}$ are the basic parameters, whose values determine the optimality of the cooperational production process, which is described by the sub-graph G_n creating the required quality determined by the admissibility condition.
The choice of the variant of the course of production cooperation process may be solved by estimating the utility function which links the basic criteria of cost, time and quality. In a case when one of the factors appears to be a stronger limiting one, we can introduce α, β , γ to the utility function.
Taking into account the probability w_n of breaking the realization of the sub-graph G_n, the utility function was formulated as follows:

$$U_N\left(\lambda^N{}_{s_N}\ \max\right)=\underset{\lambda^n_{s_n}}{MAX}\sum_{n=1}^{N} w_n\left(T^n_{\bar{s}_n}-T^n_s\right)^{\alpha}\left(K^n_0-K^n_{s_n}\right)^{\beta}\left(Q^n_{s_q}-Q^n_{s_n}\right)^{\gamma} \qquad (6)$$

where: $\alpha+\beta+\gamma = \Omega$, and Ω is a constant value, for n = 0 function $U_0 = 0$.

For the criterion of quality optimized by the admissibility condition (see: [10]) such defined utility function may be reduced to this form:

$$U_N\left(\lambda^N{}_{s_N}\ \max\right)=\underset{\lambda^n_{s_n}}{MAX}\sum_{n=1}^{N} w_n\left(T^n_{\bar{s}_n}-T^n_s\right)^{\alpha}\left(K^n_0-K^n_{s_n}\right)^{\beta} \qquad (7)$$

In the reduced form without taking into account the probability of breaking the designing w_n, the form of the function is similar to the function of utility of investment projects presented in w [4], which optimizes the course of investment only in respect of two factors – the cost and time of investment.

The admissible (N, s_N) process realization, which fulfils the above assumption may be called the optimal (N, s_N) project realization. As underlined in the introduction, it brings together two approaches to tasks by the optimization of production process design according to the quality criterion (or admissibility condition):

1) minimization of realization time with the assumed limit of production means,
2) minimization of total cost of project realization without exceeding the assumed date of termination.

This function is somehow analogous to the –Douglas production function, and also to a similar CES - *Constant Elasticity of Substitution* [10] production function. It allows for controlling the parameters α and β depending on the preferences of the decision maker relating to the equivalent value of the cost factor and realization time of the production process.

When the probability of breaking the cooperation w_n is the same for the tasks, the parameter w_n may be omitted. The sign of a sum results from the fact that in project practice there usually is a need to change or even to break the course of cooperation during the realization because of e.g.: lack of getting the required parameters during construction designing, conceptual assumptions or breaking the contract by the ordering person. Such a situation requires particular attention put on utility of previous bonds- which would probably be realized – it gives a sign of a sum, which causes adding of utility for preceding summits (additional considering previous summits). When there is sureness of carrying out the design according to the assumed structure up to the final summit, there exists a possibility to make the form of utility function simpler – with omitting the sign of a sum and probability w_n in the formula (6), that means taking into account only the parameters of the final summit.

In the case when the values of variables attributed to particular tasks are known, it is possible to carry out activities aiming at analyzing and evaluation of solutions of cooperation process works by means of utility function. This method gives a deterministic evaluation of the given values of particular criteria.

3.4. Integration with aiding system of manufacturing planning

Elaboration of classifiers which divide into groups according to similarity from the point of view of different criterions creates the basis for database structures creation – Fig. 15.

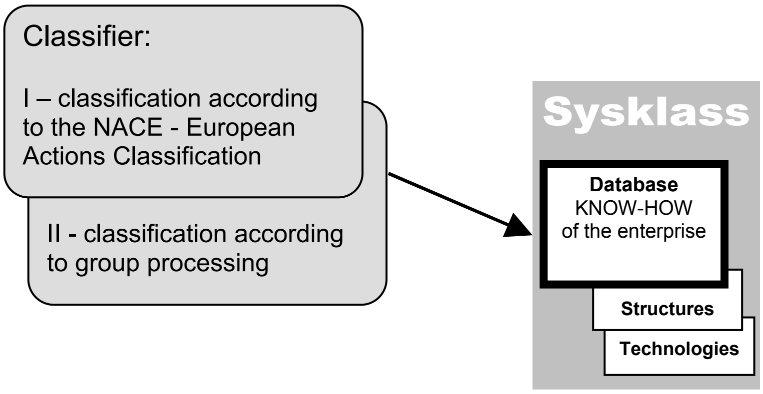

Fig. 15. Integration with Aiding System of manufacturing Designing

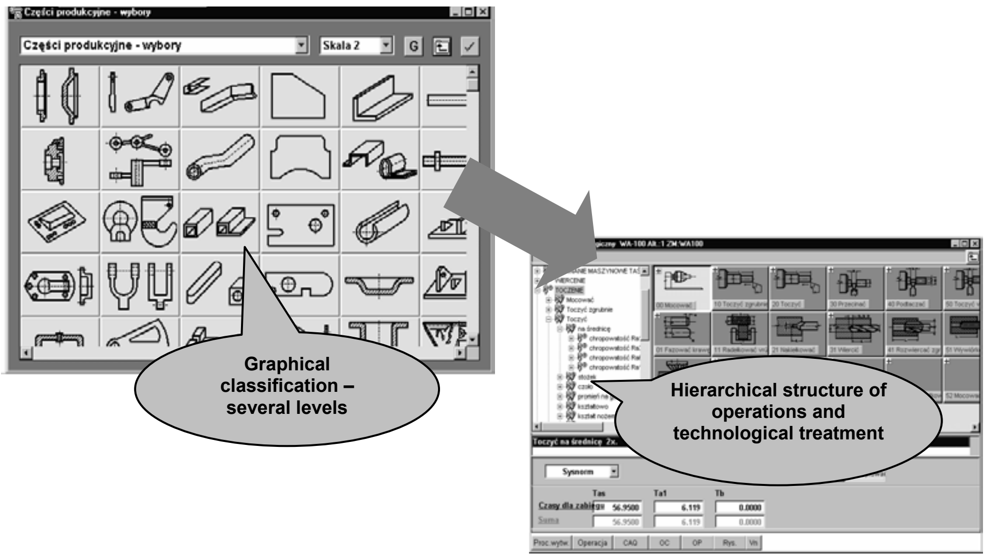

Fig. 16. Classifier – part II – classification according to group processing

Proposed system is integrated with Aiding System of manufacturing Designing – for example Sysklass. Main application of Classifier has 2 parts - classification according to the NACE (-European Actions Classification) and classification according to group processing - Fig. 15 and Fig. 16

3.5. Example of Computer Aided Cooperation

The prepared system aided of cooperation is example Computer Aided Cooperation on the website: [***www.intercooperate.com***](http://www.intercooperate.com) . Structure the first site of cooperation aiding system is presented in Fig. 17.
Systems aiding cooperation give possibilities:

- find the product,
- find the company,
- advanced search – find the product or company according to NACE.
- check the technologies ,
- design manufacturing process on cooperators' system and his resources (if you have passwords),
- others.

Fig. 17. Example of Computer Aided Cooperation - the first site of cooperation aiding system.

Systems of computer aiding cooperation create new possibilities from the enterprise's perspective which uses this kind of system and for its business partners and customers as well. These are:

- low costs – costs and subscribers' fees account for only 10% of costs which the enterprise would pay for realization of similar tasks by its workers,
- possibility of order creation at any time,
- cooperation with ERP systems- on –line orders registration in ERP systems,
- possibility of material management- order's registration on the basis of current stock on hand is possible,
- permanent control – monitoring of run and state of the ordered range of products among the business trade partners is possible ,
- current archiving of all the operations- all data about the realized and current orders are registered and made available to all the engaged enterprises.

4. CONCLUSION

Development of productivity of the enterprises requires initiating, creating and deepening of cooperative connections among different enterprises, participants of the production process, through development of methods and forms of data exchange in cooperation. The implementation of mutual data exchange concerning current possibilities of cooperative production in cooperative system customer – supplier will decrease as soon as possible, in real time, the system paralysis by accelerating the information circulation in production process in conditions of cooperation.

Active net cooperation will be modern and very effective form of complex aiding of production cooperation among system users in the future. Using the offered tools which the system provides requires setting a standard way of registration of data about the product, its production process and categorization of products and services.

The development of methods and data exchange in cooperation will allow for development and creation of New information systems of production cooperation aiding, functionally and organizationally brings closer both global enterprises and their sub-suppliers by means of taking a common type of exchanged information, normalized standard of product modelling and production process design.

A cooperation design process skilfully carried out through the three phases will allow for linking the co-operators with such possibilities relating to stock, material, possessed technologies and qualifications of staff that it will ensure the achievement of the synergic effect. In case when the values of variables ascribed to particular tasks are known, it is possible to curry out the activities.

All the entities-enterprises introduced to the system- can be subjected to classification. It will enable to search for potential customers willing to buy certain products or services of the user and automatic matching of both entities. The presented technology can be an offer for the already existing producers, virtual enterprises and many new enterprises which will exist in the future and which will offer their products for e-business and make them available as outsourcing.

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