Prof. Bożena Skołud,
M.Sc., Aleksandra Zientek
Department of Engineering Processes Automation and Integrated Manufacturing Systems, The Silesian University of Technology, Gliwice, Poland

PROJECT MANAGEMENT – TOC APPROACH

Ability of estimation and reaction on market needs decide upon being concurrent. CoPS and MTO production of the changeable products that are not repetitive generally is manufactured on a project basis. Increasing the number of project produce greater delays in their delivery time, whilst smaller number of them cause that chance of their realization on time increases but also arise wasted result from idle system. Subsets of acceptable solutions depend on sufficient conditions. That is the reason why new approach to this problem is needed. This article shows approach methodology of this task.

1. INTRODUCTION

Nowadays, the globalisation of economic activity and the diversification of customer demand is observed. The product lead-time and prices vital for customer satisfaction are subjects of negotiation with the customer [1]. Another observation has provided an improvement of complex, high value capital goods. Those goods we call Complex Products and Systems (CoPS) [2], [3]. They differ from mass production goods, but can be compared to the make to order production (MTO).

It is because large numbers of companies often have to work together in order to produce goods or serve. CoPS tend to be produced in one-off project or small-batches. The CoPS production success lies in system design project management, system engineers and integration. The complex product nature is very similar to the project one.

Projects include a wide range of manufacturing and service activities (large objects such as shifts, passenger trains and aircraft). CoPS and MTO production of the changeable products that are not repetitive generally are manufactured on a project basis [2].

Ability of estimation and reaction on market needs decide upon being concurrent. Customer is not interested in shortest possible delivery date of finished product and time estimation of it. Mostly client is interested in precise defined delivery order. The faster decision is made the more concurrent the manufacturer is. That is why modern market force from companies to precise determine their time of delivery order.

It indicates that the main purpose is either the selection of the first right variant of production flow, which performs constraints or determination of alternative acceptable solution subset, that on the basis of an arbitrary specified additional criterion we choose the best variant for. Combinatorial character of this problem makes the optimal solution impossible to attain in practice.

The higher number of orders (projects) the more increase losses results from their delays. When the number of orders is small chance of their realization on time increases but also arise wasted result from idle system. Decision-making concerning possibility of acceptance new project into the system is process of checking a large number of constraints. Subsets of acceptable solutions depend on chosen subset of sufficient conditions.

For this purpose sufficient conditions are defined. In the collection of acceptable solutions C is determined a certain its subset D, called the collection of attainable solutions. That means that in place of optimal planning and scheduling problems that are NP-hard problems, synthesis problems of acceptable solutions are considered.

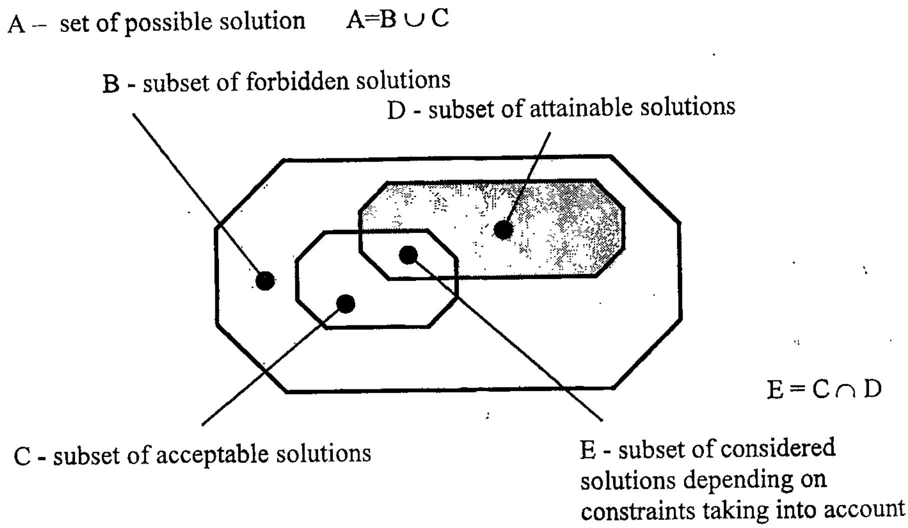

Fig.1. Subset of acceptable solutions into set of all possible solution

When talking about acceptable task problem there is so-called "suboptimality risk" solution, what means that the optimal solution may be beyond determined subset of attainable solution that go into range of acceptable solutions.

2. THE TOC APPROACH

The theory of constraints (TOC) as the philosophy of system management is the approach used for developing different techniques of project management. Due to the TOC philosophy each system has at least one constraint that is the element which both limits and synchronises production flow.

As a result of multidiscipline nature of project management it is possible to implement TOC on different project areas that lead to development of technique called "critical chain" consisted in single project scheduling or to shared resources management by concurrent projects. Constraint is everything that limits system in achieving greater efficiency.

Resources that are bottlenecks are the best exploited in the system. In order to increase efficiency instead of avoid bottleneck TOC aim at obtain as greatest number of them as possible. Utilisation of constraints boils down to job synchronisation of critical and non-critical resources.

There are three types of constraints:

- market constraints that result from government policy,
- strategic constraints that come from company strategy,
- and resource constraints which result from limited resources of the system (machines, buffer capacity, and carrying capacity).

Due to TOC we ought to precisely specify aim to which company tend towards and correctly define constraints that make achieving the sufficient efficiency difficult. Subsequent we should subordinate activity of the system and non-critical resources to the earlier defined constraints.

TOC searches the answer at 3 questions that can improve the system: what to change? to what to change?, and how to cause the change?

There are two conceptual breakthrough ideas [5]:

- First, what we call the throughput mind-set. This requires using of cause and effect to understand the impact of an action or decision in one part of an action or decision in one part of the project on the other parts as well as the ability to achieve the objective of the project – on time completion within budget and specifications.
- Second follow the basic behavior of the project management environment. The environment is characterized by dependent events with statistical fluctuations. In such an environment the income of safety time and its use is of crucial importance.

3. PROJECT SCHEDULING

The critical chain (that determines project duration) is defined for a single project as a constraint. Applying the TOC approach to project management is initially limited to management of project duration. TOC prescribes that the constraint of a system has to be identified and attention focused only on the constraint until it isn't a constraint any more.

Critical chain that determines project duration is defined for singular project. Applying TOC to project management is restricted to project duration management.

Reasons for identifying project duration as the constraint are [3]:

- Positive cash flow

Project costs often escalate as a result of extended duration. As the schedule of a project with a fixed scope increases, costs usually increase. Therefore, if a project were to be delayed, the overall effect on cash flow (or positive outcome) could be impaired.

- Cost of delays

The contingency cost of project delays could be very high ex. market share could be lost if a project is delayed.

- Preventing changes to needs

Extended project duration not only leads to escalation of overhead costs, but also leads to scope changes because stakeholder needs could be expected to change over time.

Critical chain approach makes sense only when single project is to be scheduled. When we talk about multi-project environment we find out that each critical chain of each project have no sense, because all activities of the new project depend on resource availability as well as on already implemented projects.

In the multi-project concurrent environment projects usually depend on common area of shared resources. Resource, which is overfilled, limits the number of projects that can be realized by an organisation. The main purpose is to maximise the number of projects that one organisation may implement concurrently.

It is estimated that up to 90%, by value, of all projects are carried out in the multi-project context. Moreover large projects often consist of a lot of smaller projects and they remind the multi-project environment situation. For such large project it is often practical to consider its subprojects as separate projects with individual critical chains.

The table shows the comparison of applying the five-step TOC approach to scheduling singular project and multi-project environment.

SCHEDULING	
Single project	Multi-project
1. Identification of the constraint(s) of the system lengthening project duration	1. Identification of the resource (resources) constraining the capacity for additional projects
2. Decide how to exploit the constraint(s) of the system for reducing project duration time	2. The scheduling of the resource(s) constraining the efficiency
3. Subordinate non-constraints to the decision(s) exploiting the constraint(s)	3. The scheduling of other non-critical resources should be subordinated to the schedule of resources constraining the capacity for additional projects
4. Elevate the constraint(s) – take steps to "widen the bottleneck"	4. Making an investment to acquire additional resources to make the best possible use of existing capacity
5. In case of eliminating constraint(s) having an influence on project duration time returning to Step 1	5. In case of eliminating constraint(s) limiting possibility of realization additional projects returning to Step 1

4. PROBLEM FORMULATION

Well known project management methods (CPM and PERT) are applied for single project management as well as for single CoPS design and application.

According to Stayn resources that are overloaded limits the number of projects that one organisation can execute. The objective is to maximise the number of projects, which the company is able to implement concurrently. In that context, taking into account each one big CoPS project, which usually consists of many small projects, can be treated as a multi-project environment. The following question appears: How to exploit system resources to be effective for multi-project management? (To be effective means to compete the project or CoPS in expected or planned duration time).

4.1. Methodology

Initially it is established that there is no interdependence among activities of the new project. The only requirement is that they ought to be performed during the time specified between forward scheduling start time and backward scheduling end time of the new project.

Upper Gantt's chart shows the new project which is taking into account possibility of its implementation into the system, whilst lower shows the occupancy of projects already realized in the system.

Denotations used in further examples are as follows:

– forward scheduling start time for the i-th resource and the k-th project

– backward scheduling end time for the i-th resource of the k-th project

1 resource occupancy

0 iddle resource

0 possibility of impementation of the new project

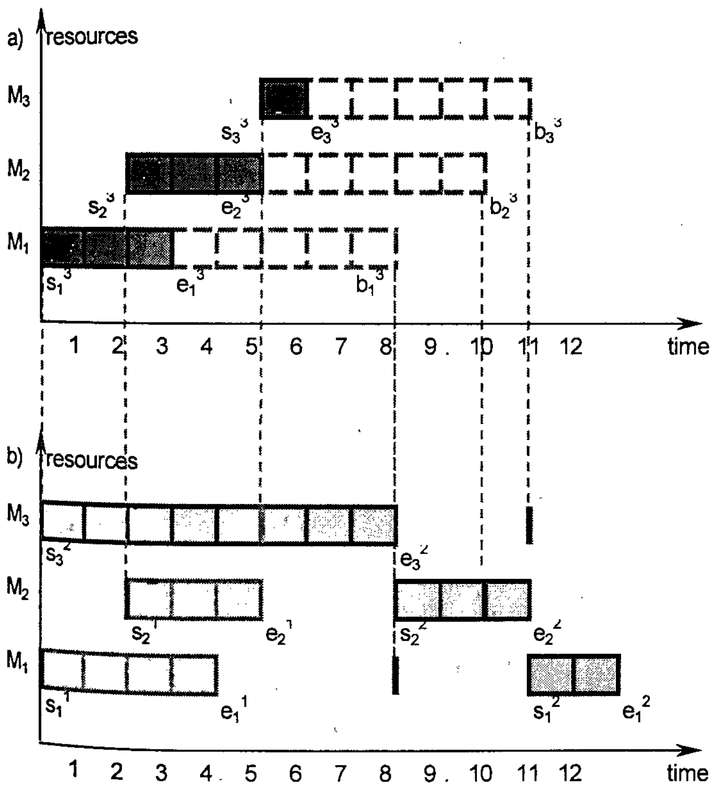

Fig.2. Illustrative example explaining the denotation for j = 1,2; k =3; i = 1,2,3; a) for the resources occupancy by the new project, b) for the projects already accepted

where:

s_i^j – forward scheduling start time for the i-th resource and the j-th project,

e_i^j – forward scheduling end time for the i-th resource and the j-th project,

s_i^k– forward scheduling start time for the i-th resource and the new k-th project,

b_i^k – backward scheduling end time for the i-th resource of the new project,

$i = 1,2,3,...,M_i$ – number of resources,

$j = 2,3,...,J$– number of already implemented projects,

$k = J+1$ number of the new project,

Δl_i – time interval of the idle i-th resource

$V_i=[l_1, l_2, ...,l_i]$

where:

V_i –vector element of the i-th resource occupancy at the l_i^t moment

$$l_i^t = \begin{cases} 0, \text{ the i-th resource is idle} \\ 1, \text{ the i-th resource is occupied} \\ \varnothing, \text{ possibility of implementation of the new project} \end{cases}$$

l_i^t – element of vector V_i and l_i^t; $t = s_i^k, s_i^k+1, s_i^k+2, \dots, s_i^k+n$

where: $s_i^k+n = b_i^k \Rightarrow n = b_i^k - s_i^k$

n –dimension of vector element V_i

For above Gantt's chart:

$e_3^k - s_3^k = \Delta_3^k$ (1 time unit)

$e_2^k - s_2^k = \Delta_2^k$ (3 time units)

$e_1^k - s_1^k = \Delta_1^k$ (3 time units)

generally:

$$e_i^k - s_i^k = \Delta_i^k \quad (1)$$

where:

Δ_i^k – task duration of the k-th (new) project on i-th resource

$$\forall i \in M_i, \exists t \in \{s_i^k,..., b_i^k\}, l_i^t = 0, \quad (2)$$

$$\exists m_i \in \langle s_i^k,..., s_i^k + \Delta l_i \rangle, \forall t_i \in \langle m_i, ..., m_i+\Delta_i^k \rangle, l_i^t = 0, \quad (3)$$

Formula (2) guarantee that there is a period of time on each resource, when the i-th resource is idle. Whilst formula (3) saying that in the considered period of time exist time interval of the idle i-th resource longer or equal duration of the new project on that resource what ensure realisation of the new project.

Future researches will be run in order to find another sufficient conditions (mathematical interdependence) among activities of the new project (operation sequencing) with refer to the possibility of their implementation into the already running system.

5. ILLUSTRATIVE EXAMPLE

Let us assume an organisation of 3 resources (M_1, M_2 and M_3). Two projects were accepted earlier for realisation (see Fig.3b). The new project P_3 is waiting for its acceptance. The Gantt's chart (see Fig.3a) illustrates resources occupancy by the new project tasks and gives possible delay of realisation each activity according to Forward and Backward Pass that still ensure realisation of this project on time. Figure 3c shows the different (alternative) method of notation the idle resources, which main purpose is to check the possibility of implementation of a new project without comparing two Gantt's charts: systems chart and new project one.

We only check for idle resource in the vector element V_i for each resource. There is no need to check for idle resource before and after that period, because implementation of the new activity beyond time content in V_i do not contain into its margin of realization. .

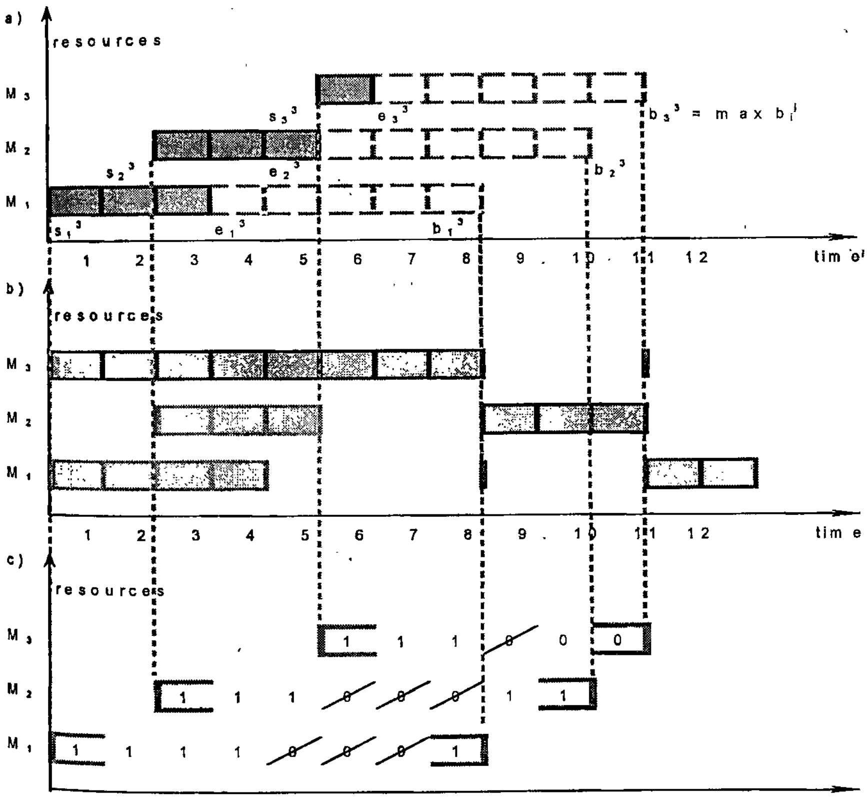

Fig.3. Acceptance of the new project: a) the resources occupancy by the new project, b) the projects already accepted, c) the alternative method of notation the idle resources

Because formulation (2) and (3) are satisfied acceptance of the new project into existing system occupancy is possible.

6. CONCLUSIONS

In the paper the approach to the complex products and systems as well as multi-project management is proposed. The Backward and Forward Pass is applied for scheduling of a new project into multi-project environment.

For the CoPS and projects realization different organizations creating virtual enterprises engaged to its resources and constraints. This requires an additional specification of the structural data describing the set of companies, machine tools, transportation delivery system, as well as the specification of the production orders (including such requirements as: the order cycle, the transportation and production routing), what will be a subject for further research.

REFERENCES:

1. Hendry L.C., Kingsman B.G.: *Production planning systems and their applicability to make to order companies*. European Journal of Operational Research, no.40, 1989, pp.1-15.
2. Hobday M.: *Product Complexity, innovation and industrial organisation*, Research Policy 26, 1998, pp.689-710
3. Editorial: *Innovation in complex products and systems,* Research Policy 26, 1998, pp.689-710
4. Stayn H.: *Project management applications of the theory of constraints beyond critical chain scheduling*. Project management 20, 2002, pp.75-80
5. Rand G.K.: *Critical chain: the theory of constraints applied to project management* International Journal of Project Management 18,2000