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Quality and Cost in Production Management Process

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The paper presents an overview of the approaches usually used in production process, specific in planning and control. The goal is to supply "the big picture" of the methods and techniques often met in the entire production process, including the planning and control phases.

Thus, some important concepts and techniques like Six Sigma, Concurrent Engineering (CE), Quality Function Deployment (QFD), Enterprise Resource Planning (ERP) and Reverse Engineering (RE) are briefly described, together with techniques and methods for reducing the value of the lead time.

The description is sustained by diagrams showing the flow of the activities involved in each method.

Keywords: production management, process management, quality management, costs, lead time reduction

0 INTRODUCTION

The goal of each production company is to maximize its profit and value. Following this, the companies try to implement new methods for production scheduling and control, but also for assuring the best possible quality, at the same price, if possible. The approach is an effect of the changing in the customers' needs.

The customer's requirements regarding features and quality of products are continuously increasing but they don't want to pay more for better products. Only the companies which offer their customers the right products to the best price will obtain a great success on actual market.

In such an economical environment, a combination between systems and methods for production planning and control, on one hand, and quality assurance, on the other hand, is a key factor making the difference between a successful and a bankrupt business.

1 PRODUCTION PLANNING AND CONTROL SYSTEMS

1.1 Overview

Production can be defined as the transforming process of material in finite goods or services using time, resource and money. That transforming will have good results if these resources are used in efficient mode.

The major role of production management is to answer at the following question: how to do this transformation in the best conditions and to obtain the optimum level between three characteristics: time, resource and money.

The cost of production is a very important factor because this factor its assessed by the customers. The price and the quality of production must be correlated in order to satisfy the client. To obtain quality products is a very important goal of production manager and of production team.

Six Sigma methodology applications can be a good solution for this scope, to obtain the quality product with a lower cost because the rate of failure is very lower [12].

We can approach the production process like a production project and we can use the methodology from project management for each subproject which consist Six Sigma methodology.

But, the problem which will arise in this approach is related to the cost. Production approach like a project will be a very expensive process and can be applicable only in some cases like aeronautics, military production, for small series of product, etc.

In production management process, we can see the Six Sigma methodology like a main project. This main project was divided in five project

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management phases abbreviated DMAIC; D – Define, M – Measure, A – Analysis, I – Improve and C – Control.

Regarding DMAIC, the questions and the problems for which the leadership must find a solution are presented in the Figure 1 [9].

If we will approach this methodology like a project, in planning phase it is necessary to recognize and establish relevant quality requirements:

- a process development plan for new products or modified products;
- the production equipment and working environment; maintenance for equipment and the working environment for ensure the availability of the production systems;
- the procedures and methods for process quality assurance;
- the operation in concordance with rules and standards, laws, defined responsibilities, quality management, as well as customers requirement;
- the monitoring and documenting of all process parameters and product characteristics, available to all competent services and departments.

In process planning stage the failure mode and effect analysis (FMEA) method is widely used.

CFD is a CE methodology that enforces the notion of concurrency and deploys simultaneously a number of completing product values in addition with quality [12]. Using the QFD concept it is possible to simultaneously address different houses of values, like house of quality, house of X-ability, house of tools and technology, house of costs, house of responsiveness, house of infrastructure, and enabling better transparency between customer's requirements and technical abilities of the company, at the same time reducing the time of product design.

1.2 How to Achieve Short Delivery Times of Orders Through Reduction of Lead Time of Operation?

The goal of each production company is to maximize its profit and value. It is possible to achieve this goal by minimizing lead times, minimizing deviations from the agreed dates, minimizing inventory, and maximizing use of resources. The connections between these elements are presented in Figure 2.

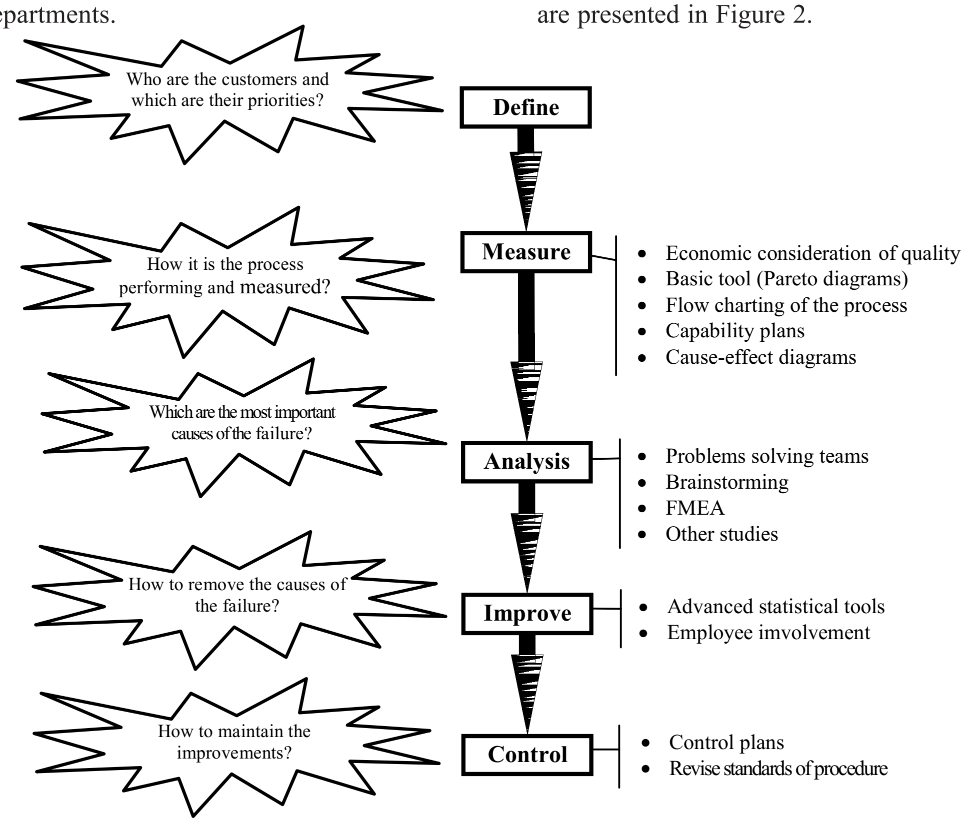

Fig. 1. The five project management phases DMAIC [9]

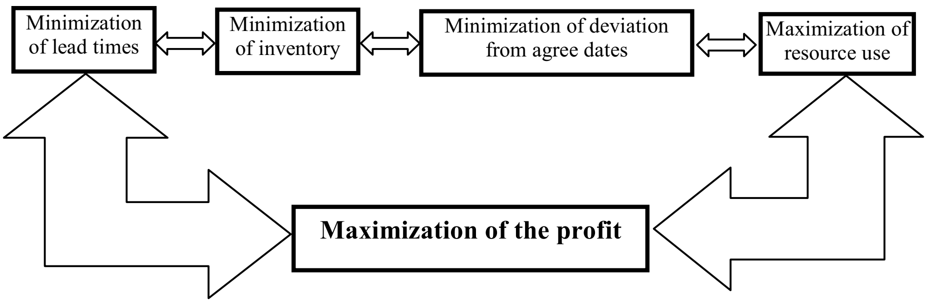

Fig. 2. Goals of economical production

1.2.1 Reduction of lead time of operation

Lead time of operations is defined as an interval calculated from the time of completing the job in previous workplace till the time of completing the job in analyzed workplace [14]. For reducing the lead time, researchers from Production Systems Laboratory may organize a creativity workshop and the problems could be solved in brainstorming groups. For this it is necessary that two stages to be completed:

1. *Analysis of workplaces in a workshop*; and for this it is necessary to carry out the following phases: designing the workshop models, designed the workplace model, designing the flow diagram and drawing the logistic curves.
2. *Searching the critical workplaces* (bottlenecks) and propose the measures for reduce the lead time of operations.

Starbek et al. [14] consider each workplace from workshop like a funnel. The objects of work are flowing into it (workload) and out of it during the treated interval.

By registering the data on the flow of jobs through the workplace it is possible to gradually draw the diagram of logistic curves that present the important logistic goals: average lead time of operation, average inventory of the operation, and performance of the operation. The logistic curve diagram presents the relations between performance, lead time, and range of workplace.

The critical workplaces are identified after analysis of the workplaces in workshop, and it is necessary to implement correction measures for reduce the lead time of operation. For a global reduction of lead time it is necessary to introduce continuous control of average lead time operation.

One of procedure described by Starbek contains three steps:

Step 1: Definition of working system features in workshop and describing the reasons for excessive lead times of orders.
Step 2: Finding most important working system in a workshop. This is the workplace that has the bigger influence on excessive lead time in analyzed period.
Step 3: Selection and implementation of specific measures in this working system.

In first step are defined the following features: mean orders time TOm, standard deviation of orders work TOs, coefficient of variation of orders work TOv, weighted mean lead time of orders TLw, standard deviation of weighted lead time LTs, coefficient of variation of weighted lead time TLv, mean performance of working systems PEm, number of finished orders n, mean inventory of orders Im, relative inventory of orders Irel.

In second step it is necessary to implement measures in order to reduce the weighted mean lead time of orders. That can be made using ABC analysis and these measures should be implemented in all working systems of workshop. As a result of these activities, the total weighted lead time during the processing of all orders in all workplaces of workshop will be reduced [2].

The third step is to identify the relation between relative inventory of orders indicator Irel and references relative inventory of orders indicator Irel*. The practice show that when Irel>Irel*, it is possible to reduce lead times in this workplace which have the bigger influence by using the optimization methods.

This procedure has been implemented to ETI d.d. company from Izlake and the results of this experiment was a good selection of measures which should ensure the shorter lead times of order. Another problem in actual production system is to

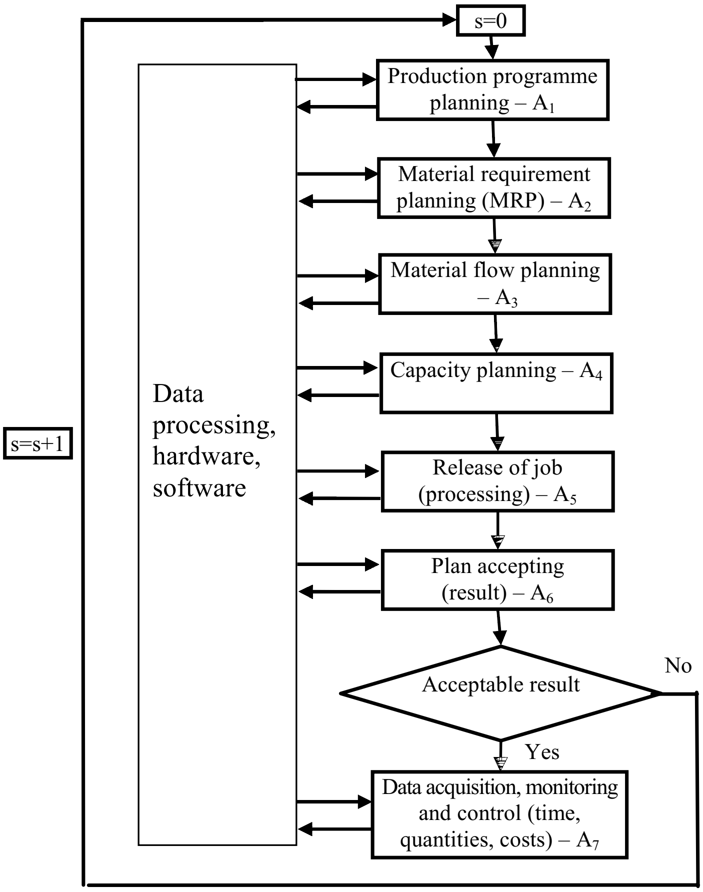

Fig. 3. Production planning and control systems [13]

find a way to achieve the optimum scheduling of job.

In paper [13], Starbek et al. present some elements which have influence in production planning and control systems.

Production planning and control systems consist of 7 modules (task), A_{1-7} as it is shown in Figure 3. The first four modules are a *planning task* and last three modules are a control task. The importance of tasks increases from the first to the seventh task.

In the framework of the actual production system, the efficiency depends on the selecting scheduling method. The scheduling methods are divided in two groups: optimization methods and non-optimization methods. After choosing the method we estimate that analytical methods which use priority rules are simple and they need minimum amount of data to generate the schedule.

In generally the following priority rules are used:

1. LRPT – activity with the longest remaining processing time are scheduled first;
2. MS – minimum slack, is scheduled first the activity with minimum slack;
3. SRPT – it is the scheduled the activity with shortest remaining processing time;
4. EDD – are scheduled the activity with the earliest start data;
5. SPT – it is the scheduled the activity with minimum processing time (activity duration);
6. FCFS – are scheduled the activity in accordance with the release data sequence;
7. LPT – are scheduled activity with the longest processing time.

The result of scheduling simulation is a set of possible schedules and the planner must select the optimum schedule. The selection of optimum schedule is a process which uses predefined criteria and different decisions models. In practice it is necessary to define the level of importance or relative weights of these criteria.

In conclusion, planning and control have a big effect in actual production systems through scheduling simulation module which allows scheduling simulation taking in account different methods and criteria for scheduling.

2 CONCURRENT ENGINEERING

The customer's requirements regarding features and quality of products are continuously increasing but they don't pay more for better products. Only the companies which offer their customers the right products to the best price will obtain a great success on actual market. A new approach of development process of products is concurrent engineering (CE).

2.1 Sequential and Concurrent Engineering

The main feature of *sequential engineering* is sequential implementation of stages in product development process [8]. The referent process stage may begin only after preceding stage has been completed. Data on the reference process stage are collected gradually and they are completed when the stage has finished, then the data are forwarded to the next stage.

The main feature of *concurrent engineering* is concurrent implementation of stages in product development process. In this case the reference stage can begin before the preceding stage has been completed. Data on the reference stage can begin before its preceding stage are collected gradually and are forwarded continuously to the next stage. Winner proposes the use of 3-T loops, where interactions exist between three levels of product development process. The differences between sequential and concurrent engineering is presented in Figure 4 [8].

This methodology improves parallelism achieved by overlapping. The main advantage of this methodology is the interaction between tracks. In each loop, transformations of inputs and outputs are performed on the basis of requirements and limitations.

The concurrent engineering is not possible to be applied without a good organization team work. *Concurrent engineering* is based on multidisciplinary product development team. The members of team have to be experts from various departments of company and representatives of strategic suppliers and customers.

The team consists of different workgroups in different phases of product development process, and each workgroup consists of four basic teams: logical team (the whole product development process is split into logical units – operation, tasks and defines interfaces and connections between individual process units); personnel team (it trains and motivates the personnel, and provides appropriate payment); technology team (responding for creating a strategy and concept, assign the quality and minimum cost); virtual team (provides other product development team members the required dates).

The goal of engineering is to achieve the best possible co-operation between the four above teams (Fig. 5a).

In the small companies the product development team consists of only two level teams.

The product development team is approached like a core team (see Fig. 5b).

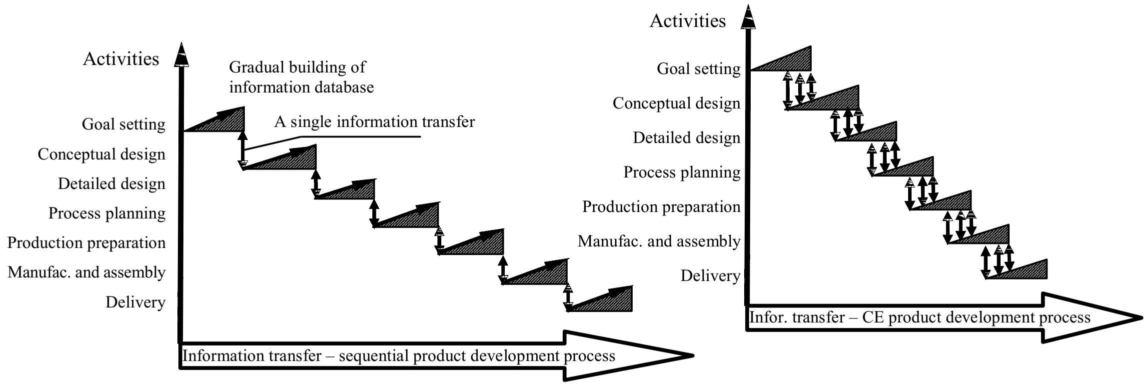

Fig. 4. Difference between sequential and concurrent engineering [8]

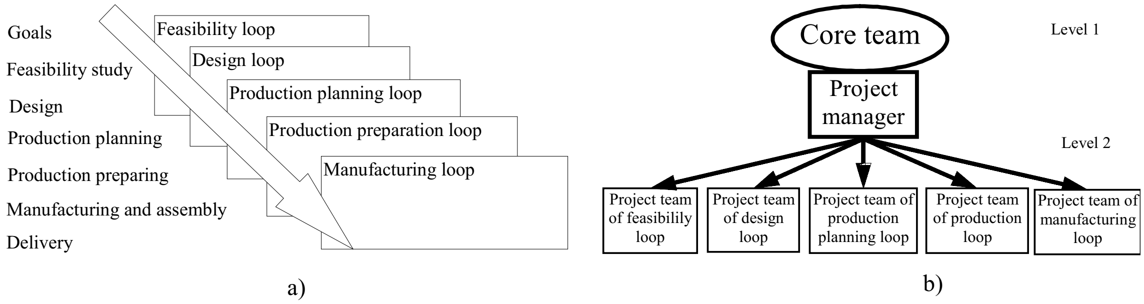

Fig. 5. Product development team

The basic element of concurrent product development is a *team-work*.

2.2 Implementation of Concurrent Engineering

The transition from sequential to concurrent product development should perform in the following two phases:
First phase: preparation for concurrent product development;
Second phase: implementation of concurrent product development.

Quality Function Deployment (QFD) and Concurrent Function Deployment play an important role in CE product development process. QFD is a central tool supporting the CE, the aims of QFD is to provide the team a classification method of deployment actions. The most widely described model of QFD is a four-level of model know as Clausing model or ASI model. The first step in part characteristic deployment is to develop a function tree – the total product is divided into subsystems and the subsystems are divided into parts and their characteristics will be evaluated.

Concurrent Functions Deployment (CFD) can be view like an upgrade of QFD. The basic organizational of CFD are:

- to increase innovation;
- organize infrastructure and improve the company's responsiveness;
- improve the cooperation inside the company and with external entities;

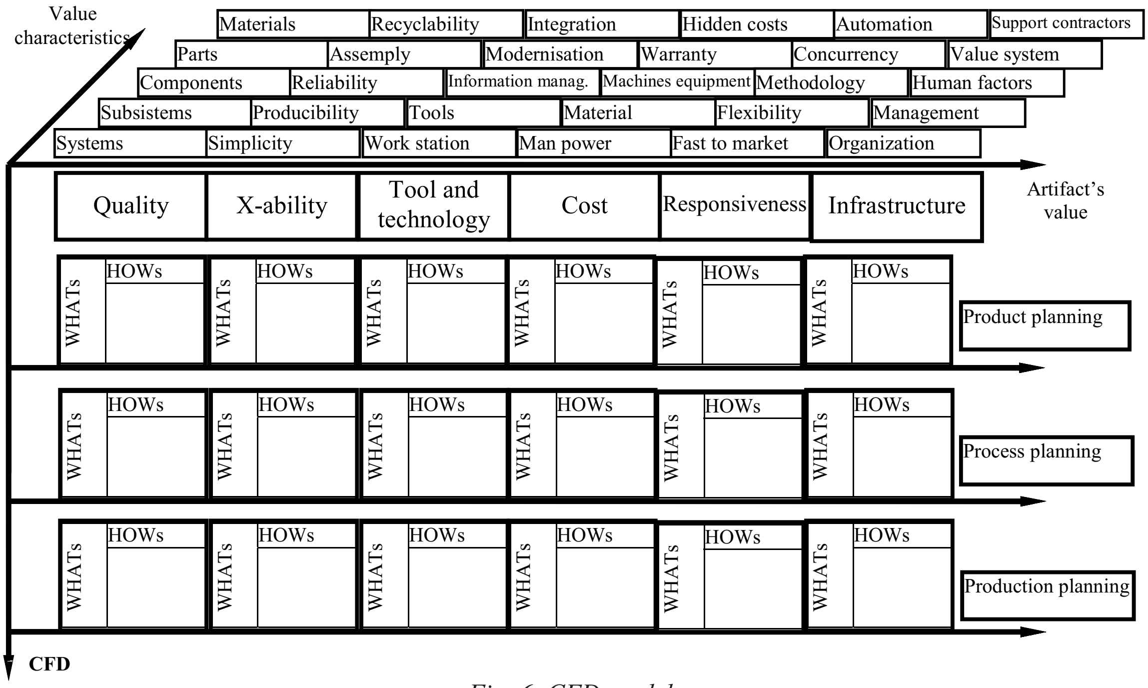

Fig. 6. CFD model

- quickly introduce new products to market in a cost-efficient manner.

CFD is a CE methodology that enforces the notion of concurrency and deploys simultaneously a number of completing product values in addition with quality [15]. With the QFD concept it is possible to address simultaneously different houses of values, like house of quality, house of X-ability, house of tools and technology, house of costs, house of responsiveness, house of infrastructure, and enabling better transparency between customer's requirements and technical abilities of the company, at the same time reducing the time of product design.

The QFD deployment process using the CFD methodology is presented in Figure 6 (Prasad 1997 quoted by Tomazevic [15]).

The CFD methodology has been implemented in small and medium enterprises and the result was an optimum result for all product values because the QFD methodology takes into account only product quality and the CFD methodology takes into account other product values like X-ability, responsiveness, tool and technology, infrastructure and cost.

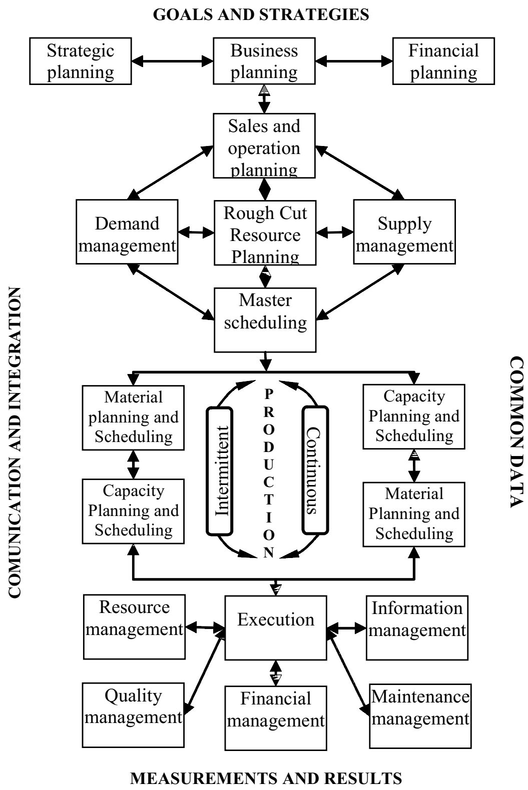

Fig. 7. Enterprise resource planning, ERP

The successful of the tools and methods that support concurrent engineering is a condition for a later transition to concurrent engineering development of a new type of product.

3 ENTERPRISE RESOURCE PLANNING

3.1 Virtual Enterprise Approach

The modern production systems have to be adaptable to changes of market. A solution of production systems to be adaptable to the changes of market is virtual enterprise approach.

Virtual enterprise is a temporary partner union of companies that join in order to share their professional knowledge, competence, resource and can thus better respond to business opportunities in their environment. Collaboration of enterprise in a virtual enterprise is based on the information and communication infrastructure [1]. In a virtual enterprise each individual partner enterprise does not manufacture a complete product, just only some operation of a product or some parts of a product.

Virtual enterprises may have different structures, for example: short time, consortium forms and extended virtual enterprise. The extended virtual enterprise form is recommended for long-term operation of virtual enterprise and this form consist in a good connection between partners, suppliers and customers for to obtain the common goals.

Responsibility for new product development within the virtual resource is taken by all partners.

Enterprises which are parts of extended virtual enterprise have to coordinate their internal enterprise resource planning systems with other ERP systems in the supply chain.

ERP is a technological evolution of MRP II. Advancement in the areas of logistics, human resources, quality, finance, maintenance, and documentation management provide today's enterprise with a tool for process better planning and control the business. Many authors define the term ERP like "Advanced Manufacturing Resources Planning", as represented in Figure 7 [1].

In ERP environment is introduced the scheduling by simulation module. The module includes all elements that are necessary for realistic scheduling.

Different methods for simulation of scheduling are used. The result of simulated scheduling is a set of different schedules and this different schedules are analysed on bases as different characteristics and criteria is selected the optimum schedule.

The optimum schedule of orders is sent to the ERP systems database.

3.2 Implementation of ERP Into Actual Production Systems

Implementing such a complex and huge software system in a company usually involves many analysts, programmers and users, and often comprises an expensive project in itself for large companies, especially trans-nationals.

In order to implement ERP systems, companies often seek the help of an ERP vendor or of third-party consulting companies. Consulting in ERP involves two levels, namely business consulting and technical consulting. A business consultant studies the organisation's current business processes and matches them to the corresponding processes in the ERP system, thus configuring the ERP system according to the organisation's needs. Technical consulting often involves programming.

The implementation must:

- be done concomitant from management;
- be done from a task force personnel from all functional areas,;
- take care of hardware requirements;
- be done step by step rather than sudden introduction;
- be done with patience, because ERP implementation takes time.

ERP implementation involves the next phases: project planning, business and operational analysis (including GAP analysis), Business Process Reengineering, installation and configuration, project team training, business requirements mapping to software, module configuration, system modification and interfaces, data conversion, custom documentation, end user training, conference room pilot, acceptance testing, production and post-implementation audit/support [1].

For small companies the implementation of computer aided monitoring and control is carried out in the following steps [1]:

Step 1: *Selection and implementation* of the ERP system in combination with PPC module. This selection can be made on the basis of system tests.
Step 2: *Automatic data acquisitions on manufacturing events*. After implementations of ERP systems it is necessary to add permanently new data.
Step 3: *Software for monitoring the actual state of production*. In this step it is necessary a permanently monitoring of process control and feedback reaction in order to improve the status of work systems and of the whole production systems.
Step 4: *Definition of reference values of lead time, inventory, range and use*.
Step 5: *Continuous improvement of process (*Deming's cycle*)*.

ERP is an integrated management process for company-wide management of a business enterprise. The concepts and techniques of ERP must be applied across all company functions. ERP integrates management processes to assure that decisions and planning are born out of the same databases, assumptions and methodology and language. ERP solutions focus on optimizing productivity by focusing on planning and executive reporting of the enterprise as an integrated unit [5]. By integration of monitoring and control modules in ERP systems are provides realistic data for planning and are taking corrective measures in order to improve the situation.

ERP is much more than a manufacturing software tool. It is a management philosophy for making and keeping promises to a better management the supply and demand sides of the business using directly integrated management systems [5]. The focus is on results, improvement of the competitiveness in the marketplace and improvement of the overall company business performance.

4 REVERSE ENGINEERING

The customer requirements it's the most important factor which the leadership of production factory have to take in account.

Because every day the market demand asks to change the production, the factory has to find the way to be aligned with the demand of the market. If the production factory doesn't find the way to align of the demand market, this factory will not survive and will fail.

The one of new success approach in design and development of products it’s Reverse Engineering. This method it’s an unconventional approach for design and development of products.

In conventional design of products, the process starts with the geometrical modelling using a CAD systems, then the information are exported in standard format (like IGES points/STL binary, ASCII data, DXF polyline, VDA point or IGES/STL surfaces) and imported in the same format to CAE systems (allowing numerical model simulation) and/or to a CAM systems (allowing to generate the trajectories of tool).

This unconventional approach can be applied when the scope is improvement or optimising some parts of existing products or when do you want to simulate or redesign some parts of product for which don’t have a CAD data format. The three steps in RE process are: *digitising, data segmentation* and *data* fitting [6], [10] and [11].

The *digitising phase* is generating conceptual model from physical model through 3D-scanninig techniques aided by specialised software’s for model reconstructions. This phase is the process of gathering data from a 3D surface.

This process of acquiring data can be made in different forms using new technologies for data capture as laser, camera, and vision and analogue probe systems. This phase, called *digitising*, is described in Figure 8.

Technologies for gathering data are adopted in accordance with the physical model. Therefore, CCD cameras and laser have the advantages for a fast and precise gathering data and can be used for soft materials because are two non contact methods, but the price is very high and can’t be used for reflective materials or for oil and wet parts.

Classical contacts have good precisions in all axes, have a low prise, it’s possible to scan all types of material (beside the soft materials) and can be used for the very big products (like airplanes, ships, big machines and devices), but the scanning speed is lower and can’t be used for soft materials, it’s not possible to determinate the roughness of the surfaces [10].

5 INTEGRATION CONCEPT IN MODERN MANAGEMENT

5.1 Concepts and Theories

Growing globalization and more complex business environment are conditions which have requests to rapidly increasing management effectiveness and require application of new management theories which can respond to modern business conditions. Modern management theories offer some concepts for increase effectiveness of organizations.

Those theories, described by Bobrek et al., are General system theory, Balanced Scorecard, CASE tool for information systems design [3].

Another theory is “Six competitive games” of Gharajedaghi quotation by Bobrek et al. [3]. Together, these six games have dominated the

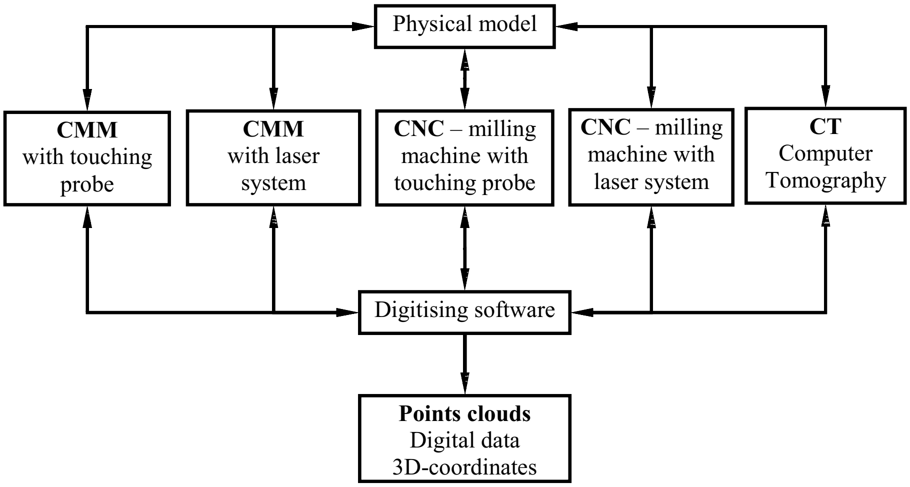

Fig. 8. Digitising phase using different technologies for gathering data from 3D-geometries and generated data [11]

management scene and each paradigm has its own unique mode of organization.

A new theory is developed on the Dale examination and the result of that is summarised into four areas of interest: *integration in organisational behaviour* (integration is considered as the degree of coordination and cooperation necessary to overcome the differentiation and establishment of common outlook), *integration in the systems concept* (integration and alignment increase the efficiency and the effectiveness), *integration in the quality management* (that is the degree of the alignment and the harmonisations with the European model of TQM, levels of TQM activity stages of quality culture) and *integration in the management systems standards* (is associated with alignment, harmonisation and compatibility and implies a single top-levels system) [4].

The benefits of systems' integration can be: improved operational performance, internal management methods, higher motivations of staff, fewer multiple audits, enhanced customer confidence, reduced costs.

The design approach is useful in creating management systems of organizations in economic field and is fully accepted in international standards of management.

Integrating all requirements, techniques and tools in those standards leads to a unique concept of management which appears in the term Integrated Management Systems (IMS) [3].

The system definition is *an element structure and its relation and processes accomplishing the purpose of the system.*

The graphic model of the system **S** is presented in Figure 9, and for a complete

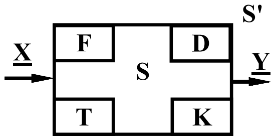

Fig. 9. Graphic model of the system

identification of a system is necessary to define the following systems quantities:

F is system goal functions, that determines the goal of which the systems exists and systems should achieve at a specific point in time.

K represents system characteristics; these are the characteristics of system and its elements by which are identified and compared with other systems of the some class. The systems characteristics are in connection with the process of measurement, analysis and development.

X represents inputs, that are independent variables and these can be materials, energy or information's.

Y is output and this represent the result of the work transformation in the system and this can be materials, energy or information.

T represents the system transformation operator and this is the rule based on which the input into system are turns into an output.

D represents the system status and this is understood as the capability of system to perform process or not.

S' represents environment of the system.

Scientific management approach application, for every concrete system, means application of different methods and tools group, which in concrete conditions results the best effects [3]. In traditional management the commonly used tools are: strategic planning, costs management functional organizational structure, detailed description of work tasks, standard work between performers and promoters, management by objectives, financial measurements, etc.

The modern management theory is a comprehensive number of techniques and tools, which could be effectively used to design management systems. It is very important to choose adequate techniques, which can contribute to integration of different goals of management and affirmation synergetic effect on all levels of organisation. One of scientific approach to management is Conductor Orchestra method of Drucker quoted by Bobrek et al. [3].

5.2 Management System Design Methodology in Management Standards

The management systems design processes are given by ISO 9001:2000. Advanced Product Quality Planning (APQP) is a logical methodology for general product design, which has been developed in the automotive industry.

Product quality planning is a structured method of defining and establishing the steps necessary to assure that product satisfies the customer [4]. The goal of product quality planning is to facilitate communication with everyone involved to assure that all required steps are completed in time. The basic principles of implementing APQP plan [4] are:

- *organise the team* – assign responsibility to a cross of functional team;
- *define the scope* – it is identify the customers needs, expectations and requirements;
- *team to team* – that include regular meetings with other teams;
- *training* – assign a training program for communicates all requirements and development skills to fulfil customer needs and expectations;
- *customers and supplier involvement* – customer may initiate the quality planning process with supplier;
- *control plans* – are written descriptions of the systems for controlling parts and processes;
- *concern resolutions* – during the planning process the team will encounter product design;
- *product quality timing plan* – that is the first task which should be developed by planning's team;
- *plans relative to the timing chart* – the success of any program depends on meeting customers needs and expectation in a timely manner at a cost that represent value.

It is possible to find an analogy between APQP principles and methodology of QMS implementation. The object of designing in the management systems fields is an unequivocal process structure of the business system and process model. This approach is founded by Deming and is very well know the 14 management principles, which are new ISO 9000:2000 standards condensed into eight principles.

The whole implementation of the teamwork principles and concurrent engineering is possible by using a computer aided tool (CASE - Computer-Aided Software Engineering), which involves technology of communication for interchange the information of the project teams in different design phases. *CASE is the use of computer-based support in the software development process.* This definition includes all kinds of computer-based support for any of the managerial, administrative, or technical aspects of any part of a software project.

In paper [4] the authors find that adequate theory, practical methods and tools for design of the organizational and management systems exists. In the same time, some correspondences with computer-aided tools are revealed. These connections may improve the design procedure effectiveness and efficiency and it is possible to use APQP model as a basis for the standardisation of management systems design procedure.

6 CONCLUSIONS

Nowadays, the modern production systems must be adaptable to the changes on the market.

Most of the products are manufactured by order and for this reason, the production lots has been reducing. On the other hand, following the customers' needs and trying to always have only satisfied customers, the manufacturers discovered the importance of implementation of some new methodologies: Concurrent Engineering in combination with Six Sigma, often in the framework of an ERP environment.

The implementation of concurrent engineering starts by creating a specific environment that facilitates communication and collaboration between members of team work, but also between separate organisations and departments within the same company.

In the same time, the companies who apply concurrent engineering must see the implementation process as a project. This approach makes concurrent engineering a powerful development tool that can be implemented early in the conceptual design phase, when the majority of the products' costs are committed.

Close to the techniques developed in Concurrent Engineering, and often combined with them, the Six Sigma methodology assures the increase of the quality of manufactured products, and also the visible decrease of the number of rebuts and of the production costs.

In the framework of the Six Sigma environment, the collecting and analysis of data is an individual process which doesn't take care about the synchronisation between departments. Another weakness of the Six Sigma methodology is the lack of control used to sustain improvements achieved. Taking into account all these elements, in order to assure a superior quality for all the products, and also just in time products, the manufacturing companies have to join in efficient mode, both methodologies, combining them in a creative way. Growing globalisation on a market is the element which gave requests for organisations to rapidly increase the management effectiveness and to require the application of the new management theories.

Six Sigma and Concurrent Engineering may give a solution which helps them to obtain a fast response to customer needs and to line up to modern business requirements.

7 NOMENCLATURE

CE	Concurrent Engineering
QFD	Quality Function Deployment
CFD	Concurent Function Deployment
DMAIC	Define, Measure, Analysis, Improve, Control
FMEA	Failure Mode and Effect Analysis
LRPT	activity with the Longest Remaining Processing Time
MS	Minimum Slack
SRPT	scheduled activity with Shortest Remaining Processing Time;
EDD	scheduled the activity with the earliest start data;
SPT	scheduled activity with minimum processing time (activity duration)
FCFS	scheduled activity in accordance with the release date sequence;
LPT	scheduled activity with the Longest Processing Time
ERP	Enterprise Resource Planning
MRP II	Material Resource Planning II
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
RE	Reverse Engineering
IMS	Integrated Management Systems
APQP	Advanced Product Quality Planning
CASE	Computer-Aided Software Engineering

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