Strojniški vestnik - Journal of Mechanical Engineering 54(2008)9, 588-606 Paper received: 26.05.2007
UDC 658.5 Paper accepted: 07.07.2008

Project Management of Product Development

Janez Kušar[1,*] - Lidija Bradeško[1] - Jože Duhovnik[1] - Marko Starbek[1]
[1]University of Ljubljana, Faculty of Mechanical Engineering, Slovenia

The market requires that companies continuously reduce their product and process development time and costs, in order not to lose their competitive advantage on the global market. Short product and process development time in combination with low costs and achievement of required quality can be obtained only by integrating project management methods with concurrent engineering elements.

Project management of orders combined with concurrent engineering elements allows for considerable reduction of development time, reduction of costs, and provides for a higher quality of order/product [1].

Order planning phase is very important in integrated product/process development. In the traditional product/process development, on average only 3% of total order development time is used for planning, while at the concurrent concept this time increases to about 20% [2].

The company which has decided for the integrated product/process development as a mode of its operation, first has to carry out organization and information redesign of its business process, as well as to make system and operation project management guidelines.

The paper presents an example of project management implementation in a company, the emphasis being on the development of planning procedure and project management of orders, as well as design of a project dossier.

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Keywords: project management, orders management, project management office, dossier, cuncurrent engineering

0 INTRODUCTION

Mass production was prevailing production concept till the end of the 20th century, while today's companies favor a transition to project type of production [3]. This is not only the case in companies which manufacture special equipment for new investments – this transition can also be seen in companies which have used mass production traditionally, e.g. in automotive industry [4], so the companies nowadays have to deal simultaneously with continuous and project processes (Figure 1).

Continuous processes are carried out for an "indefinite period of time" - for an unknown customer; they are used (according to the market demand) for providing new quantities of previously developed products.

Project processes are carried out once or in standard repetitions; they are aimed at achieving precisely defined objective, for a known customer, and their duration is limited to a "definite period".

This paper is concerned only with market-oriented projects arising from known-customer orders. An order is an expression of a wish or requirement for supply or delivery of a specified product or service. The project-oriented way of implementation of such orders will be further dealt with as project management of orders.

1 INTRODUCTION OF PROJECT MANAGEMENT OF PRODUCT DEVELOPMENT

The company deciding for project management of orders has to perform four important steps:
Step 1: training of employees for project management of orders.
Step 2: organization and information changes in company operation.
Step 3: creation of system- and operational guidelines for project management of orders.
Step 4: definition of a method for planning and project management of orders.

*Corr. Author's Address: University of Ljubljana, Faculty of Mechanical Engineering, Aškerčeva 6, Ljubljana, Slovenia, janez.kusar@fs.uni-lj.si

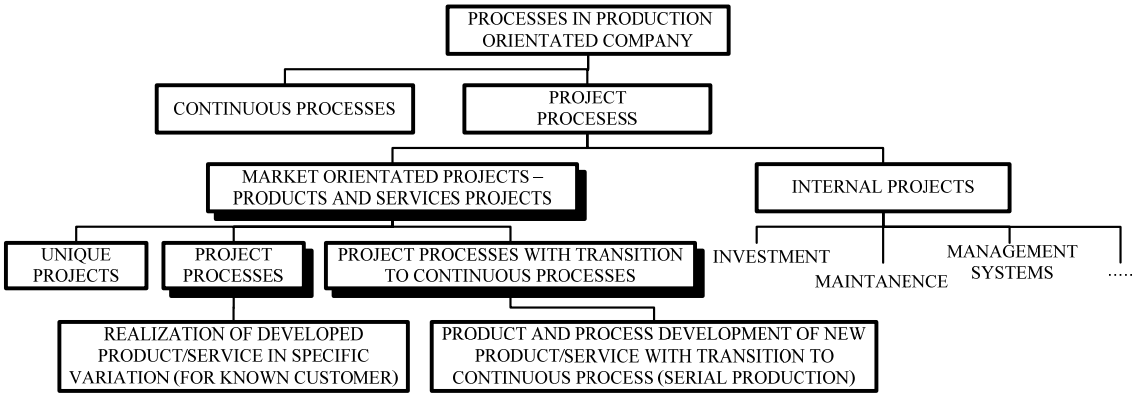


Fig. 1. *Processes in a manufacturing company*

1.1. Training of Employees for Project Management of Orders

Analyses of company personnel qualification for project management of orders reveal that this knowledge is insufficient [5]. For a successful use of project management it is necessary that a critical mass of employees be appropriately trained; these people will be project managers, project team members and heads of organizational units responsible for project management.

For project management of orders it is important to have the knowledge on: teamwork and team philosophy [6] and [7], project management [8], network planning techniques [9] and [10], concurrent engineering [2], organization of manufacturing systems for project management support [4] as well as IT and communication support of project management [11].

1.2. Organization and Information Changes in Company Operation

The implementation of project management of orders in a company requires considerable organizational and informational changes. In companies with traditional functional organization, a transition is usually made to a project-matrix organization [12] in which project teams take over competences and responsibilities (from functional units) for planning and project management of orders. By this organizational change, the functional units of the company become operators of project activities "only", responsible for observing deadlines and quality assurance.

By increasing role of projects in companies, the need for suitable technical and organizational support increases along with the selection of suitable labor forms. At the end of 1990's, a special organizational form appeared in companies: a project management office (PMO) [12]. This term is based on the fact that there is usually a multi-project environment in companies and project management is a mode of company operation.

The need for PMO appeared due to the requirement for employing unified project management methods and standards, as well as for achieving higher efficiency in the management of time, resources, costs, quality, risks and IT support.

PMO can be considered a critical link between strategic company management, which is responsible for managing the company, and the project management, which is responsible for managing projects [3], as presented in Figure 2.

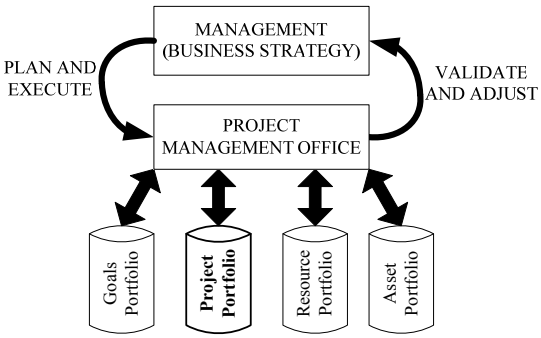


Fig.2. *PMO as a link between strategy and project management*

PMO is not only professional, technical and administrative aid for project management of orders; it is also becoming an important service of strategic management of the company for synchronous coordination of various company portfolia, a source of information and its flow between strategic and project management, management of processes for data exchange and acquisition on project progress, as well as for harmonization of project portfolio with strategic plans of the company [3].

In order to make PMO operation successful it is necessary to ensure its position in the company organization scheme. Our experience shows [5] that project-matrix structure is the most suitable form; in this structure the PMO is responsible for project support on one hand, and to the company management on the other (Figure 3).

Strategic management has to form a special body for operational supervision of project management (and PMO) – a project board [7]. Several project boards may be established in the company for various projects.

It is suggested that the PMO be filled with the following personnel:

- PMO head (management of PMO and coordination with the company management and managers of functional units),
- project information system administrator (information support for projects and PMO),
- project process analyst (planning and management of projects and project portfolios),
- control analyst (project control),
- project management administrator (data acquisition and distribution).

PMO head has to have support of the company management and a sufficiently influential position in order to be able to coordinate the labor with functional units in the company.

A two-level structure is developed for organization of teamwork [1] and [13]. It consists of: project board (core team) and project teams for the implementation of a particular project (Figure 4).

The company management appoints the project board; it takes care of the planning and implementation of project management policy and strategy, and for guidance and coordination of project-team work.

Project board is permanent and heterogeneous, consisting of project managers and heads of organization units. The general manager or his deputy, who is in charge of the project management, usually manages the project board.

Project team is managed by the project manager. Permanent members of the project team are representatives of organization units, who work on the project throughout its duration. They are responsible for communication and information transfer between the project team and organizational units.

Project team can be extended with temporary members participating in the project for a limited time frame. In the integrated product development, the temporary members form sub-teams, which are responsible for activities in concurrent engineering loops [1] and [2].

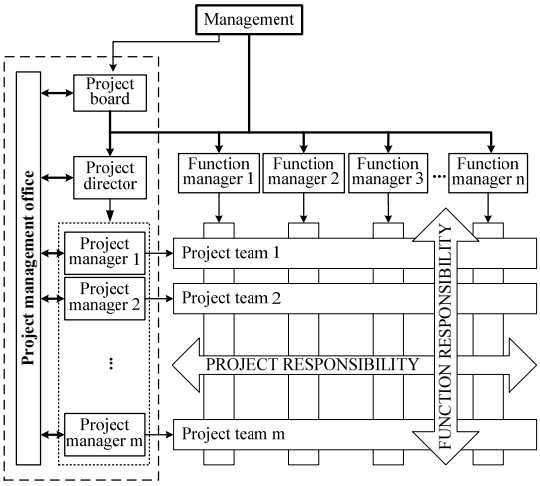


Fig. 3. *PMO location in the project-matrix organization*

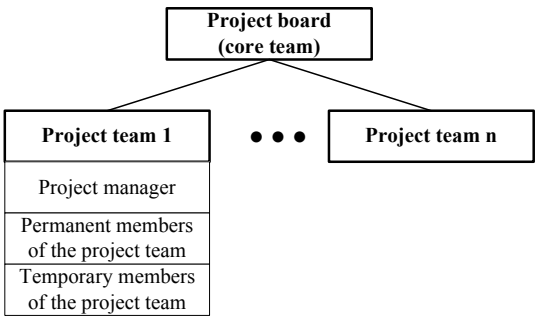


Fig.4. *Organization of teamwork for integrated product development*

1.3. Creation of System- and Operational Guidelines for Project Management of Orders

Studies have shown that a company, which has decided to use project management of orders, has to develop system- and operational guidelines (Figure 5), which have to be harmonized with other system- and operational guidelines of the company.

For each project it is necessary to set up a project dossier – a data warehouse of all data/documents produced in the project lifetime. For easier survey, the project dossier is divided into folders with documents related to a particular process type (Figure 6). The project dossier has to be accessible to all project participants via the intranet.

1.4. Method for Planning and Project Management of Orders

The studies on introduction of project management of orders in companies have shown that the order management process has to be dealt with in a holistic manner. The data and experience obtained during tender preparation are an important source of information for the implementation project preparation.

Order management project therefore has to be carried out in two phases:
Phase 1: Planning and management of a tender.
Phase 2: Planning and management of implementation project.

1.4.1 Planning and Management of Making a Tender for an Order

A tender is made on the basis of customer inquiry or internal initiative in an organizational unit of the company. Company management should check whether the proposal is in accordance with objectives and strategies of the company. If it is, then the company management orders that a tender be made and appoints an ad hoc project team, which (on the basis of customer requirements and market analyses) obtains as much input data as possible and examines the history and experience on similar, reference projects.

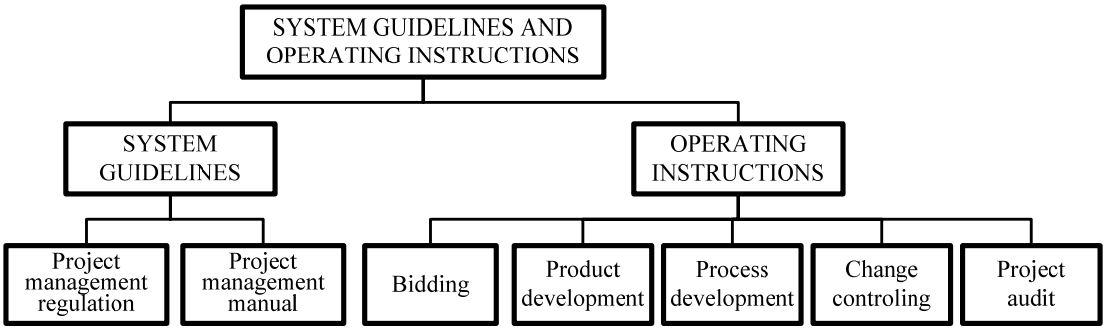


Figure 5: *Overview of system- and operational guidelines for project management of orders*

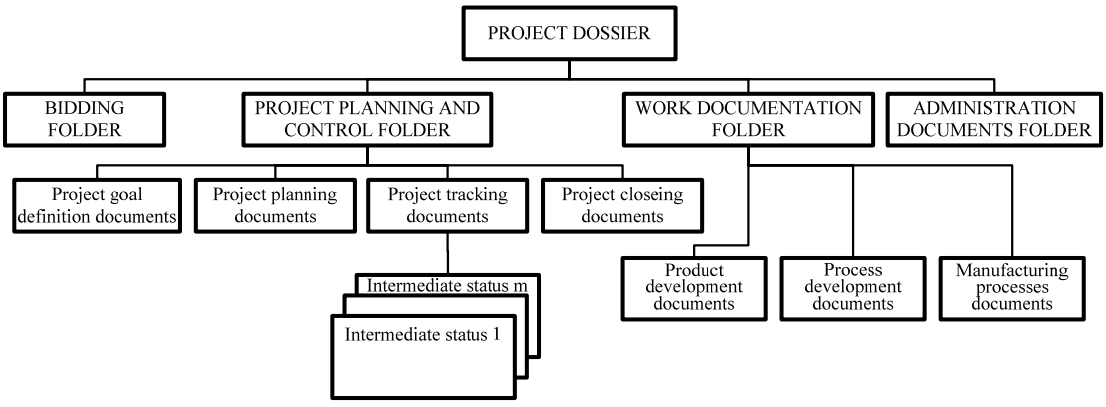


Fig. 6. *Contents of the project dossier*

The course of making a tender is presented in Figure 7.

Ad hoc project team is usually managed by the marketing-department representative. Its members are from development, technology, manufacturing and, when necessary, from other departments of the company. The future project manager is also a member of the ad hoc project team. The result of work of the ad hoc project team is an estimate of the economic justification and feasibility of the project, including risk analysis. If the estimated economic justification and feasibility of the project are promising, the tender is made in accordance with the customer requirements. The tender contains technical and financial data, as well as data on deadlines – the Gantt chart of the project tender.

If the tender is successful, a contract is signed, which defines: project deliverables, quality, deadline with milestones, costs and method of payment, supervision and report on the course of the project.

By signing the contract the foundations are made for planning and management of the implementation project.

1.4.2 Planning and Management of Implementation Project of an Order

Planning and management of the implementation project of an order consists of a logical sequence of all the activities needed for the preparation and implementation of the project, as well as the documents resulting from individual activities.

Planning and management of the implementation project of an order for new product development is similar to execution of a previously developed product, the difference being in individual activities.

Project manager and project team are responsible for the execution of planning and managing of implementation project.

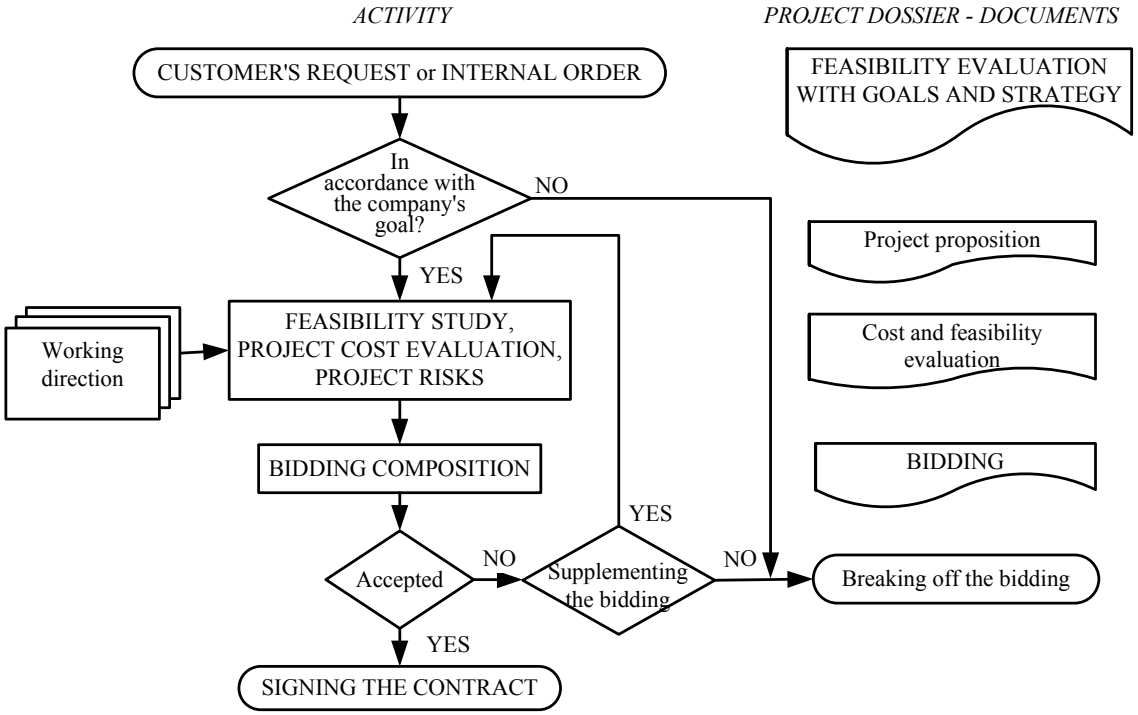


Fig. 7. *The course of making a tender*

Planning and management of implementation project of an order is carried out in four steps (Figure 8):
Step 1: definition of the objective of implementation project.
Step 2: planning of implementation project.
Step 3: execution and monitoring of implementation project.
Step 4: completion of the implementation project.

1.4.2.1 Definition of the Objective of Implementation Project of an Order

In order to define the objective of implementation project it is necessary to:

- order implementation project,
- define the implementation project.

Implementation project is ordered by the contracting authority - company management on the basis of the signed contract. Order of the project contains the data on: customer, project deliverables, project manager, project team composition, conditions for project implementation as regards on time, costs and resources.

Definition of the implementation project is made by the project team on the basis of a detailed study of the project and the book of customer requirements. Project definition consists of: summary of the project - tender; starting

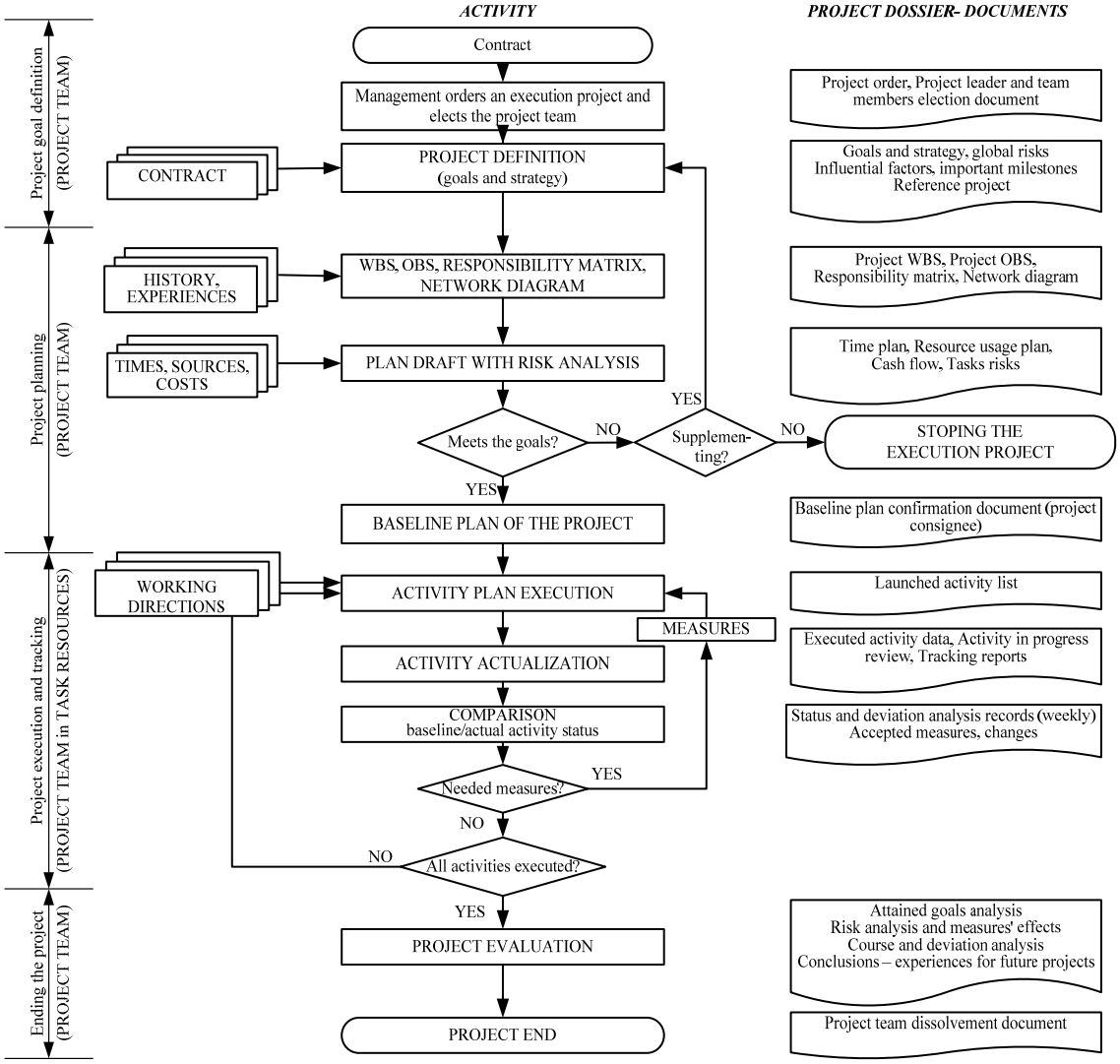


Figure 8: *Steps in planning and management of implementation project of an order*

points for the project - tender documentation; general and specific objectives of the project; strategies for meeting the deadlines; scope of the project; data on project manager, his deputy and project team members; data on other project participants: suppliers, sub-contractors, customer, control; reference project; feasibility study; the way of ensuring the required resources; investment dynamics and ROI data; pre-calculation; milestones: external and internal; general risk assessment; the way of monitoring the project and reporting to the contracting authority and to the customer.

1.4.2.2 Planning of Implementation Project of an Order

Planning the implementation project is a responsibility of the project team, which has to make:

- work breakdown structure of the implementation project – WBS,
- organization breakdown structure of the implementation project – OBS,
- responsibility assignment matrix,
- network diagram of the implementation project,
- proposal of the plan of the implementation project: schedule, plan of resources and costs, risk analysis with measures, communication plan and plan for management of changes,
- basic plan of implementation project activities.

Work breakdown structure (WBS) represents a structured breakdown of the whole project [8], [10] and [14] into smaller and manageable tasks. WBS is important in terms of the management of time, costs and risks of the project [15]. WBS defines the scope of the project and all the activities necessary for project objectives completion.

WBS of the implementation project (Figure 9) consists of four main groups of tasks: definition of project objective, planning the project, implementation and monitoring of the project, and completion of the project.

The tasks listed comprise activities for all phases of the implementation project.

The "Implementation and monitoring of the project" task is – on the basis of the assembly structure of the product – divided into groups of parts, sub-groups and parts (PtBS – part breakdown structure).

The tasks defined within PtBS can be performed sequentially or parallelly [5].

Planning and manufacturing of components is treated in a process manner (PsBS – processes breakdown structure) (Figure 9).

Tasks (packages of activities) can be performed sequentially or parallelly [5].

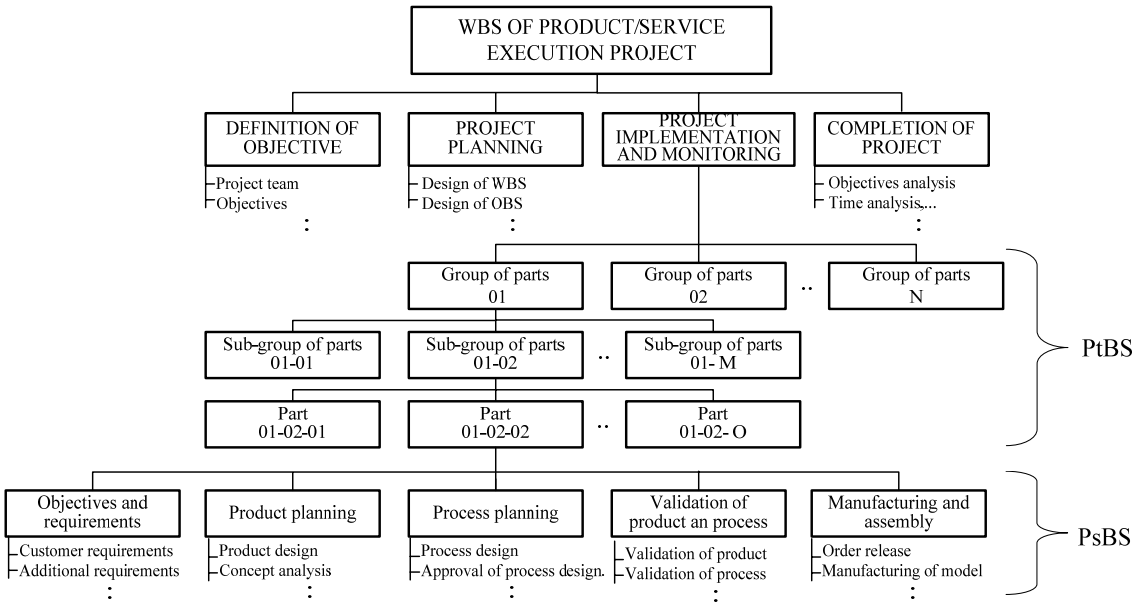


Fig. 9. *WBS of implementation project*

Organization breakdown structure (OBS) represents an organizational breakdown of the company organization units, which are responsible for the execution of WBS tasks/activities [16]. In addition to internal organizational units of the company, OBS also comprises external contractors (suppliers, sub-contractors, consultants, auditors).

The last OBS level consists of resources to be used for the implementation of project activities. An example of an OBS project is presented in Figure 10.

OBS is a temporary organizational structure whose lifetime is equal to the lifetime of the project. It is managed by the project manager and project team members.

If organizational units that are part of the OBS are on various locations, OBS may be organized as a virtual company (by using modern IT and communication means) [17].

Responsibility assignment matrix (RAS) links the project organizational structure (OBS) with the project labor structure (WBS). Responsibilities of operators from OBS versus tasks and activities in WBS are presented with symbols [16]. An example of RAS formation is presented in Figure 11.

Project network diagram is a set of mutually logically linked activities, which have to be carried out in a precisely defined logical sequence and interconnected. It can be made in a form of event- or activity network diagram. Preference is given to activity network diagrams due to their simplicity and possibility of concurrent execution of activities (partial dependence) [9].

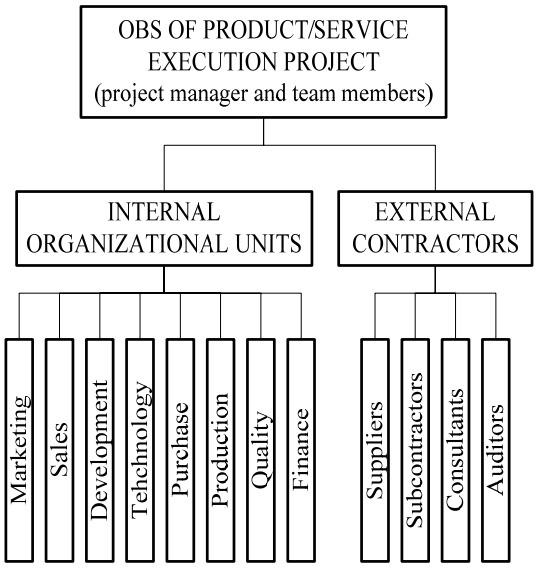


Fig.10. *OBS of the project*

Links between activities in a network diagram can be (Figure 12).

Direct connections - observed activity has to be finished before new activities can start e.g. testing can only be carried out after the prototype has been made; the prototype has to be made before testing.

Responsibilities (OBS) / Product and process development phases (WBS)	OPERATORS IN THE COMPANY								EXT.OPERATORS			
	Marketing	Sales	Development	Technology	Supply	Manufacturing	Quality	Finance	Suppliers	Sub-contractors	Consultants	Auditors
Definition of project objectives	P		S				S	I			I	
Project planning		S	P	S	I	S	S		I	I		
Implementation and monitoring of the project	P		S	S	S	S	S	I	S	S		I
Project completion		P					S					

Legend:
P – primary responsibility
S – secondary responsibility
I – informational responsibility

Fig.11. *Responsibility assignment matrix*

Partial connections (dependencies) - allow concurrent execution of two or more activities.

External connections - join activity of the observed project with activities of other projects.

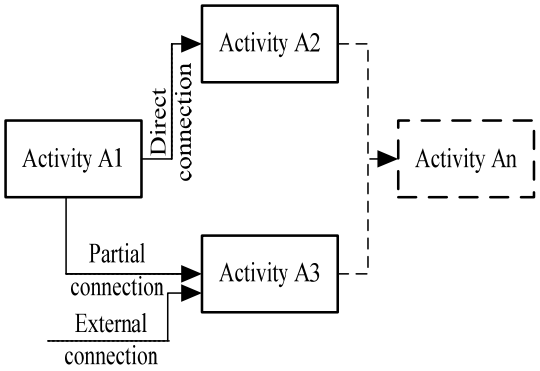


Fig.12. *Project network diagram*

When defining links between project activities in project management of orders, extended with concurrent engineering elements, it is necessary to define the maximum partial overlapping and thus maximum overlapping of tasks defined in WBS on PtBS and PsBS levels.

Network diagram is a starting point for analyses of duration, resources and costs of the project. In view of preserving the prescribed links between project activities, the network diagram is an indispensable aid for monitoring the project progress.

Proposal of the implementation project plan with risk analysis is an output of the project team in the project design phase. It contains: schedule with milestones, resource load plan, plan of costs, and risk analysis of the project.

Schedule with milestones comprises: durations of activities, date of starting the project, starting and completion dates of activities including milestones, deadline for project completion, dates of milestones, critical paths and time slacks.

Resource load plan can refer to labor force, production means or materials. Each activity is allocated one or more resources.

Project manager and team members examine the resource load profile and if conflicts arise, they search for a suitable solution (in collaboration with PMO and managers of functional units at a project board meeting), which still assures the achievement of project objectives.

In resource analysis the PMO has to harmonize the project portfolio with the resource portfolio.

Project cost plan is made on the basis of: fixed costs of activities, fixed costs of project management, and variable costs of resources used for carrying out activities.

Project cost plan is acceptable if the planned total project costs do not exceed the costs approved when the project was ordered.

PMO has to harmonize the project portfolio with the company costs portfolio.

There are several methods available for risk analysis of implementation project activities [7] and [18]. An analysis of available methods has revealed that the most suitable tool for project management of products and services is the table of “critical success factors”, as it represents an analytical aid to find, evaluate, reduce and remove risk. It is elaborated by the project team, which is responsible for planning and implementation of the project. Analyses should be as extensive as possible and they have to cover all possible problems.

Procedure for designing the table of critical success factors consists of risk analysis and risk management.

Risk analysis consists of the identification of problems or events, definition of the probability of their arising, evaluation of their consequences and incidences, and risk calculation [8].

During the identification of problems, all tasks and activities, which are defined in the project WBS, are analyzed. Potential problems of individual task are entered into the critical factor table (Table 1). If it is not possible to identify problems related to a particular task, the latter is omitted.

Quantitative risk analysis is defined by risk activity level, which is calculated on the basis of the following estimates:

- probability that a problem or risk event will arise,
- consequences of a problem or risk event,
- incidence of a problem or risk event.

Table 1. *Table of critical success factors*

Risk analysis						**Risk management**		
No.	Activity/ problem	Event probability *EP*	Consequence estimate *CE*	Incidence estimate *IE*	Risk factor *RF*	Measures *P* – preventive *C* – corrective	Responsibility	Signals
1.	Activity A	3	2	4	24			
:	:	:	:	:	:	:	:	:

Table 2. *Probability that a risk event (RE) will arise*

Estimate	Event probability *EP*
1	very small
2	small
3	middle
4	great
5	very great

Table 3. *Estimate of consequences (CE) of an event*

Estimate	Consequence estimate *CE*
1	very small
2	small
3	middle
4	great
5	very great

Table 4. *Event incidence estimate (IE)*

Estimate	Incidence estimate *IE*
1	never
2	very rarely
3	rarely
4	often
5	very often

An interval scale from 1 to 5 is used for the estimates [8] and [19].

Probability that a problem or risk event will arise is estimated by means of Table 2.

In order to estimate the consequences of a problem or risk event, Table 3 is used.

In [8] the risk is defined only by estimating the probability of a risk event arising and the estimated consequences. The paper deals with project management of cyclically recurrent projects, so experience derived from similar past projects can be used for estimating the incidence probability of a risk event.

Table 4 is used for estimating the incidence of a problem or risk event.

RF – risk factor for the problem identified is calculated by:

$$RF = EP \times CE \times IE$$

EP – probability that a problem or risk event will arise,

CE – evaluation of consequences if a problem or risk event arises,

IE – evaluation of incidence of a problem or risk event arising.

If the calculated risk factor $RF \leq 60$, the risk is considered normal; no measures need to be prepared in advance. If $RF > 60$, the risk is high and measures need to be prepared in advance.

The threshold value of 60 has been set on the basis of the Paret principle [20]: 20% of risks (high-risk-level activities) can cause 80% of problems or damage.

Risk management means definition of measures and responsibilities for risk prevention, and signals that warn us when a risky event might occur.

If the risk factor (*RF*) reaches the critical value (60), it is necessary to pay special attention to the problem. An additional analysis of possible sources of problems is made, and suitable prevention or corrective measures are predicted.

A table of critical success factors also has to contain the so-called signals, i.e. events signaling a new problem to responsible operators and thus allowing them to trigger a suitable measure(s).

Project manager, project team and operators of activities are responsible for the implementation of measures.

Project team forwards the finished proposal of a project plan to the contracting authority (company management or project board), which issues a decision on the confirmation of the baseline project plan, which consists a "copy" of project plan proposal, which does not change during implementation and monitoring of the project – it serves as a reference value for an analysis of deviations of actual project course from the planned course.

Change of the baseline project plan (elaboration of a new baseline project plan) must be confirmed by the contracting body.

1.4.2.3 Implementation and Monitoring of the Project

Project manager (via the project management office) takes care of activity plan implementation. Data on activities that have to start at a specified time are sent to team members (according to the responsibility assignment matrix) and thus to the competent organization units (included in the project OBS). Heads of these units take care of the elaboration of operative activity implementation plan within the planned date of start and end of activities, and for the elaboration of required documentation. Suitable system- and operating instructions are used for the implementation of activities.

Project manager is responsible for actual information on project status, i.e. periodical information retrieval on realization of activities. The project team members from individual organizational units are responsible for on-time actual data acquisition on activity realization.

Project manager and project team make a deviation analysis of the current project status in comparison with the basic project plan; they analyze reasons for deviations and search for solutions to continue the project.

PMO helps the project manager during project updating and deviation analysis. PMO performs a simulation of possible scenara, and on the basis of these the project manager suggests corrective measures. Problems that cannot be solved by the project team, are sent (together with a proposed solution) to the project board.

Project manager documents all measures adopted, including data on holders of their activities and results achieved.

Measures that influence other projects, always have to be analyzed by the PMO and confirmed by the project board.

1.4.2.4 Completion of the Project

After the project has been completed, the project manager and project team members perform project evaluation, which includes: analysis of objectives achieved, deviations of time, resources, costs, risk analysis and important conclusions for future projects. The project board confirms the project evaluation.

Project is completed when a total project dossier has been elaborated; it comprises full documentation on project planning and management, as well as technical documentation on project deliverables (see Figure 6). All these documents should be forwarded to the project management office for archiving. After the project dossier has been archived, the contracting body discharges the project manager and dissolves the project team.

2 CASE STUDY

Implementation of project management of orders in real life is presented in a case of a company which is a development supplier of components for automotive industry. Four groups of products are the most important in its production programme: gearshift mechanism, hand brake, pedal component and engine bonnet pivot. As a development supplier, the company participates in a development project already in a new car concept, and it cooperates with the car producer at least three years before the production starts. By selecting a supplier, the car producer makes an important decision, because the supplier should be a long-term reliable partner; on the other hand, the supplier is in a risky position, as it is not known in advance whether a particular car model will be a market success.

In 2004, the company management decided to introduce project management as a mode of company operation. They did it in four steps:

Step 1: Training of staff for project management.
Step 2: Organization and information changes.
Step 3: Creation of system and operational guidelines.
Step 4: Implementation of test project management of orders (As-Is / To-Be process).

2.1. Training of Project Management Staff

The company management found that for introduction of project management into the company, the employees do not have the required knowledge. In collaboration with the Centre of excellence for modern automation technologies on the Faculty of Mechanical Engineering in Ljubljana several seminars and workshops have been organized, where the employees obtained the required knowledge on project management, teamwork, creativity, communications and concurrent engineering. The seminar participants

tested their newly obtained knowledge in solving actual problems in their company.

2.2. Organization and Information Setup

In the past, the company was organized according to the functional principle. Based on an analysis of a suitable company organizational form, the company management selected a balanced matrix company organization. The decision was based on the fact that project decision-making is equally divided between the project manager (regarding project management and achievement of goals) and heads of company functional units (for carrying out project activities and ensuring product quality).

A product and service project board was appointed, managed by the company executive director and consisting of project managers and functional unit heads.

A PMO was established for organizational and technical project management support. It was managed by the project management assistant to the executive director and it consisted of project management administrator, project control analyst, administrator and all professional project managers.

Fig.13. *Car pedal component*

MS Project software was selected as a key tool for project management IT support. It was used together with MS Office software (Excel, Outlook), which will have to be linked with ERP and PLM system in the future. A question arises, which MS Project functions can be done by ERP system, and which tasks and project management processes should still be managed by MS Project. The implementation of web version of MS Project Server will also be analysed. A project management portal was established on the company's intranet; all project participants can obtain the project-related data on that site.

2.3. Creation of System- and Operational Guidelines

Company management organized the creation of system- and operational guidelines. Project team, responsible for project management implementation in the company, made project management rules, where project management system was defined, as well as a procedure for project planning and management, and the content of a project dossier. The project management rules were adjusted to the company quality management rules. As an aid to project managers and project team members, a project management handbook was made, which contained practical guidelines and templates of all documents appearing in folders and project dossier. For execution of individual processes (bid, product and process development and validation, test manufacturing) operational guidelines have been used that had already been made for the company quality management system, so they have been just harmonized with the project management rules.

2.4. Implementation of Test Project Management of Orders

Company management selected a product and process development order of a car pedal component (Figure 13) as a test project during the introduction of project management of orders. Contract for that project had already been signed; this was therefore an implementation project of an order.

Project team was appointed for the implementation of the project; its members were representatives from all the company functional units, and a senior project manager was elected as the project manager.

The project team carried out the project planning and management process in accordance with the procedures defined in chapter 2.4.

The implementation project plan of the car pedal component order was carried out in four steps:

- Definition of project objectives.

- Project implementation plan.
- Project implementation and monitoring of the project.
- Completion of the project.

2.4.1 Definition of Project Objectives

In order to define the project objective, the project team carried out two creativity workshops. During the first workshop the team members learnt about their tasks, competences and responsibilities, and they thoroughly studied the tender documentation and subject of the contract.

During the second workshop the team members defined project objectives, suitable strategies, scope of the project, global risks, impact factors and identified the project participants.

2.4.2 Project Implementation Plan

According to the plan of introduction of project management, the company management decided to create two project implementation plans for product order:

- Using the existing way of order process implementation (As-Is)
- Using the project-management-of-orders system, extended with concurrent engineering elements (To-Be).

On the basis of the project definition, the project team made a project implementation plan in several creativity workshops.

Project team members first made the project WBS structure (Figure 14). For individual project phases they defined tasks, subtasks and work packages as shown in Figure 9; they also defined the required project activities. Altogether 340 activities were defined.

During the definition of implementation step activities and project monitoring, all processes, methods and procedures, defined by the APQP methodology for automotive industry, were precisely reviewed [21].

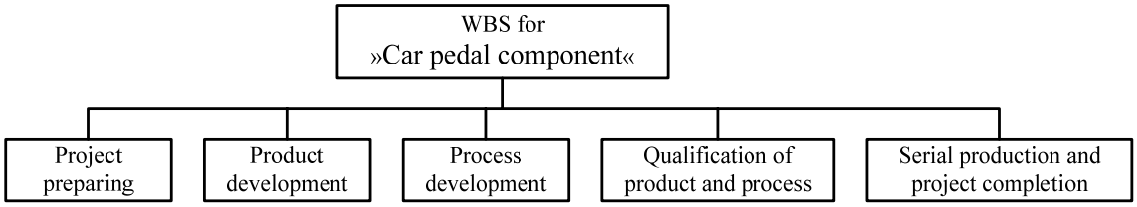


Fig.14. *WBS for car pedal component*

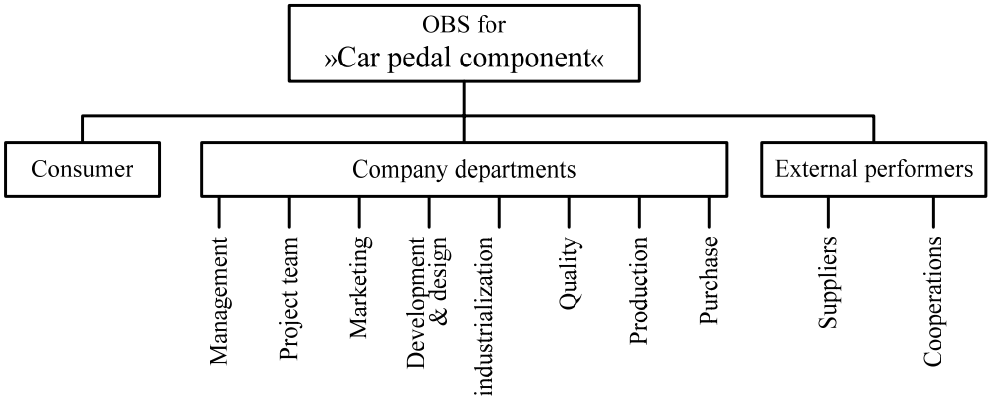


Fig.15. *OBS for car pedal component*

Responsibilities (OBS) / Product and process development phases (WBS)	Management	Project team	Marketing	Development & design	Industrialization	Quality	Production	Purchase	Cooperation	Suppliers
Project preparing	S	P	S	I	I					
Development and design of product		S	I	P	S	S		I		
Development and design of process		S		S	P	S	I	I	I	I
Qualification of product and process	I	S		S	S	P	S	S	S	S
Serial production and project completion		P				S				

Fig.16. *Responsibilities assignment matrix for car pedal component*

Afterwards, team members formed a project OBS (Figure 15); they included into it those functional units of the company, which would provide resources for the implementation of activities, as well as external suppliers and sub-contractors. Responsibilities assignment matrix was made for easier coordination between project management and functional-units management (Figure 16). The responsibilities were presented by symbols (P – primary, S – secondary, I – informational responsibility).

During project planning, the creation of a project network diagram was the most difficult and most critical task for the project team. Only the network diagram that realistically and logically defines dependencies between project activities can serve as a useful tool for further planning and management of project implementation. Project team members made activity card (label) for every activity. Then they logically connected activities into a network activity diagram (Figure 17). In this process they defined the As-Is order implementation project process as precisely as possible.

After the network diagram had been made, the project team members defined duration of each activity they allocated the required resources and defined the data required for cost analysis.

MS Project software was used for time-, resources- and cost analysis. A period of 644 days would be required for project implementation using the As-Is process.

During the risk analysis all project activities were checked, risk types were defined, risk levels were calculated and preventive and corrective measures were defined if necessary.

The output of the project team was a proposal of the implementation project plan with risk analysis. It was sent to the project board for confirmation. After the project has been confirmed its implementation could begin.

After the order implementation project had been made in accordance with the existing implementation process, the project team began designing an implementation project plan, which would, as far as possible, include elements of concurrent engineering.

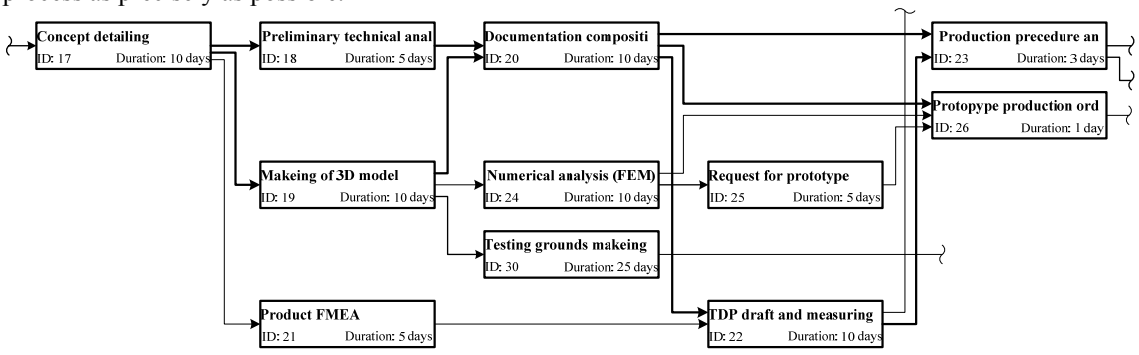
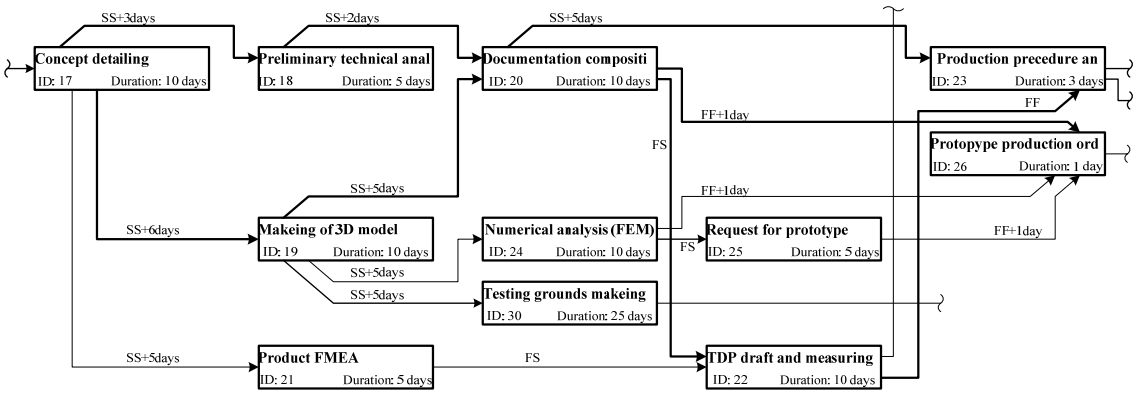


Fig. 17. *Part of network diagram for car pedal component (sequential engineering)*



Legende: SS – start to start; FS – finish to start; FF – Finish to finish

Fig. 18. *Part of network diagram for car pedal component (concurrent engineering)*

Procedure for designing implementation project plan is similar as in a classical project implementation, with the following important differences:

1. It is necessary to ensure as much as possible concurrency of process implementation, defined by the APQP methodology [21].
2. It is necessary to find which activities within processes can be executed concurrently, so that maximum overlapping is achieved, and to define the values of partial dependencies between network diagram activities.
3. It is necessary to define concurrent engineering loops.
4. It is necessary to form teams (sub-teams) for implementation of concurrent engineering loops.

It is obvious that by incorporating concurrent engineering elements, the project implementation changes because its processes overlap (APQP) and the network diagram structure changes, too – the goal is to achieve as high concurrency as possible. Because of a partial overlapping of interdependent activities, their execution time may even extend – without extending the project duration time. Incorporation of concurrent engineering elements does not influence the WBS and OBS project structures (Figure 18).

The process overlapping and partial dependencies between project activities require a high level of collaboration between the holders of responsibilities and operators of activities, so it is necessary to introduce concurrent engineering loops [1] and [2], as shown in Figure 19.

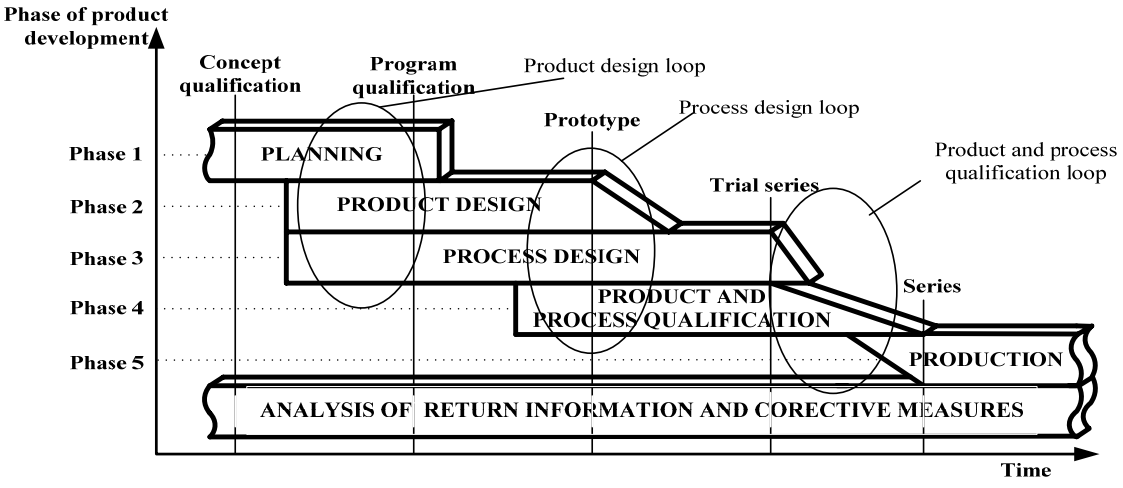


Fig. 19. *Concurrent engineering loops during product and process development for car pedal component*

Three concurrent engineering loops were defined for the car pedal component project:

- product development loop
- process development loop
- qualification of the product and process loop.

Within an individual loop, various activities are being carried out concurrently by resources from various functional units and by external contractors. To ensure on-line information exchange between operators of various activities, sub-teams are formed within the project team for implementation of concurrent engineering loops (Figure 20).

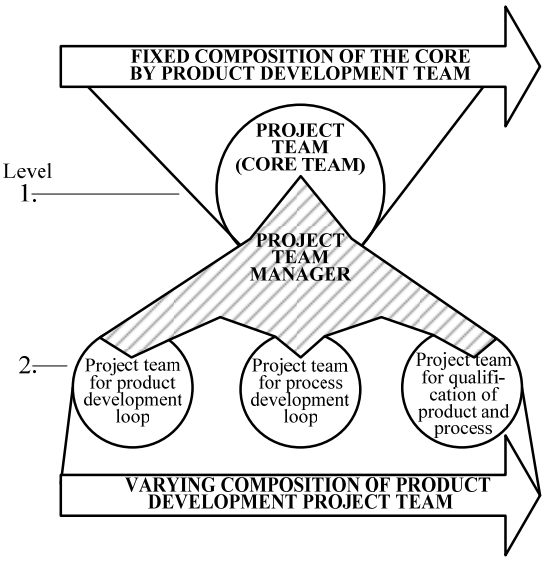


Fig.20. *Team structures of concurrent engineering loops*

Loop teams consist of representatives (operators) from those functional units, which concurrently carry out activities of an individual concurrent engineering loop.

Loop teams do not have permanent members – they change depending on the loop for which the team is responsible or depending on the activities that will be carried out within this loop.

After all changes had been made, the project implementation time was reduced from 644 to 419 days, which is 35% reduction of project duration.

The company management was aware that project implementation on the basis of concurrent engineering elements is a very demanding process and its implementation is associated with a high risk. Nevertheless, they decided to implement this project in a new, more demanding way. They were aware that they have insufficient knowledge of concurrent engineering, so they asked the experts of the Centre of excellence for modern technologies on the Faculty of Mechanical Engineering in Ljubljana for technical assistance.

2.4.3 Implementation and Monitoring of the Project

According to the project plan, the project manager sends (in electronic form – using MS Outlook) to team members and functional unit heads the information about activities that should start with a special document containing data on planned activities, their duration and the planned date of beginning and completion. The same document has fields for entering dates of actual beginning and completion of activities.

A project team member from a particular functional unit is responsible for monitoring the implementation of activities and for current reporting on status of activities to the project manager, while functional unit head is responsible for the implementation of activities within the prescribed deadline and for achievement of the required quality. Reports on the implementation of activities are made once a week.

Project manager promptly stores the actual data into the MS Project software.

Project team makes a weekly snapshot of project status. It finds out which activities have been finished completely and which have been finished just partially. On the basis of these data a calculation of the current project status is made. By comparing it with the initial plan, the team members find which activities are delayed, which are carried out according to the plan and which are carried out faster. Also important are the analyses of critical activities, critical paths and the costs incurred so far. Problems and risks are identified (so called "status indicators" are an aid to the team members); they can be overcome by triggering an appropriate action plan made during risk analysis, and additional measures can be taken if necessary.

Project manager and team members are responsible for the implementation of measures. If a measure exceeds their competences, they forward it to the project board or to the company

management. Project manager continuously keeps records of measure results.

Weekly results on current situation snapshot are published on the project management portal, listed by the whole project activities and separately by activities allocated to individual functional units of the company.

Project manager reports on the project status and on the measures taken at the project board meeting, where the project status is being harmonized with other current projects.

An analysis of all current projects, especially in terms of the used resources and costs, is prepared by the PMO.

According to the contract, the project status data are sent to the customer, who thus has an accurate overview of the project status and problems, and can participate in their solution.

2.4.4 Completion of the Project

Project is completed when all the project activities have been carried out and the objectives met. When the project has been completed, the project team made evaluation of project including:

- Meeting the deadlines and financial limits: project was completed within the agreed deadline and within the approved costs.
- Use of internal and external resources: there were great difficulties with internal resources associated with coordination of their involvement in other projects.
- Quality of project management and project deliverables: was in accordance with project management rules and with the customer's expectations, which was confirmed by two audits made by a reviser authorized by the customer.
- Overview of the planned and performed risk measures: there were many more preventive and corrective measures prepared than actually used.
- Experience obtained that is important for similar future projects: regular meetings of project team. Project team members have to be well prepared for a meeting – this is a precondition for short end effective meetings.

Likewise all other project dossier documentation, the final report was also published on the project management portal.

After the project has been completed, the company management dissolved the project team and appoints the sales department for execution of post-contract obligations.

2.5. Establishment of Multi-project Environment

After the analyses of the first results of planning and management of the test project, the company management decided that all new projects should be managed using the described procedure (one year later, more than 30 projects have been planned and managed in this way).

PMO is responsible for project coordination, especially for the use of common resources and cost management.

Every week PMO sends a report on cumulative status of all projects to the company management; the projects are classified in three categories:

- carried out according to the plan,
- carried out according to the plan with some discrepancies that are manageable,
- critical, whose discrepancies are difficult to control or even beyond control.

In each individual case the company management acts according to its strategy.

3 CONCLUSION

This paper deals with market-oriented and value-added projects and services, especially cyclically repeated projects, i.e. projects of implementing a previously developed project/service in a specific form, in accordance with the customer's requirements, and projects related to new product/process development, which are afterwards submitted to a mass production.

Introduction of project management into a company, as a mode of business process operation, is a demanding task, because it requires changes in the integration and focus of company functional units to the goals of the company. It is important that project objectives have higher priorities than functional unit priorities, and that project-friendly environment is created in a company.

It is proposed that project management be introduced in the company in four steps.

Before introducing project management into a company, the employees have to be trained to use new knowledge, methods and techniques required for project management – and change their way of thinking: from focus to the company goals, the employees have to focus to the customer/market goals ("customer is the king" principle). Project management requires continuous and on-line exchange of information, so it is important that employees learn to communicate in a way of giving and receiving the right information, at the right time and related to the task they perform. In practice, a problem of hiding information within the functional unit (or within an individual person) can still be found. It is therefore important that the company establishes a knowledge management system.

Success of introduction of project management also depends on organizational and informational changes. Authors of this paper propose that a transition from a functional to a balanced-matrix organization be made, with a possibility of further transition to a project-type organization. Our proposal can be justified by the fact that in this case an important advantage of functional units is retained. In these units specialist knowledge is concentrated, employees have permanent training available and they get to know modern trends in their field of speciality. Members of functional units participate in projects temporarily and during that time they give their maximum contribution to a successful project implementation. Working in projects, they gain experience, which they later transfer back to their functional units.

It is important that (especially in early phases – during project and process development) the best and most qualified personnel is involved, so that decisions are made as fast as possible and optimal from the quality and cost point of view.

In the company there are several projects running concurrently (even several dozens), so it is essential to set up a PMO, which supports the projects and provides management of the whole company project portfolio.

Project management procedures have been formalized by making system and operational guidelines for project management, where procedures for the implementation of individual project phases and the contents of required documents, which make a project dossier, are defined precisely.

The market requires as short delivery time as possible and the highest possible quality, so it is necessary to extend the order/service project planning and management methods with concurrent engineering elements. Concurrent engineering is based on teamwork, track and loop process of implementation and incorporation of concurrent engineering tools. IT and communication support are required for incorporation of concurrent engineering elements (ERP, PDM and PLM systems).

The proposed methodology of project management implementation, as well as planning and management of products/services was tested in a company, which is a development supplier of components for automotive industry. On the basis of the proposed methodology of project planning and management for products/services, the company management decided to create two versions of a project plan.

The results have shown that the version of project implementation, extended with concurrent engineering elements, has some essential advantages: shorter delivery time, higher quality, somewhat lower costs, simultaneous elimination of errors already in the concurrent engineering loops and not in later phases as in the sequential engineering. In spite of a higher risk, associated with the implementation of a project in this way, the company management decided to test the proposed new method and carry out the project in a new way. The customer agreed with that.

Insufficient capability and willingness of project participants for on-time, continuous and accurate communication and exchange of data and information turned out to be the main problem during project implementation.

Nevertheless, the results achieved have been encouraging, so further research will be focused mainly on the definition of criteria for formation of concurrent engineering loop teams, their internal and external information integration, and to methods for effective personal and technical communication.

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