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Team Building for Implementation of Concurrent Engineering Loops

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1. Introduction

The essence of modern production is to make a product that a customer needs, as quickly and as cheaply as possible. Under these conditions, only a company that can provide customers with the right products, produced at the right time, at the right location, of required quality and at an acceptable price, can expect global market success. A product that is not produced in accordance with the wishes and requirements of customers, which hits the market too late and/or is too expensive, will not survive competitive pressure (Kušar et al., 2007; Dickman, 2009). The customer should therefore participate in the process of concurrent realisation of a product as early as possible (Starbek et al., 2003; Kušar et al., 2004) He can participate by expressing his wishes and requirements regarding project definition. The customer should be a temporary member of project teams in concurrent product realisation loops.

The main feature of sequential product realisation is the sequential execution of stages in the product realisation process (Prasad, 1996). The observed stage of the product realisation process can only begin after the preceding stage has been completed. Data on the observed process stage are built gradually and are completed at the end of the stage—the data are then forwarded to the next stage (Rihar et al., 2010).

In contrast with sequential product realisation, the main feature of concurrent product realisation is the concurrent execution of stages in the product realisation process (Prasad, 1996). In this case, the observed stage can begin before the preceding stage has been completed. Data on the observed process stage are collected gradually and are forwarded continuously to the next stage (Rihar et al., 2010).

A transition from sequential to concurrent product realisation considerably reduces the time and costs of product realisation (Rihar et al., 2010), as shown in Figure 1.

It can be seen from Figure 1 that product definition costs rise uniformly in sequential product realisation, because of sequential execution of product definition activities (marketing, product draft, product development, elaboration of design documentation, material management), while production costs rise rapidly, due to long iteration loops for carrying out changes or eliminating errors.

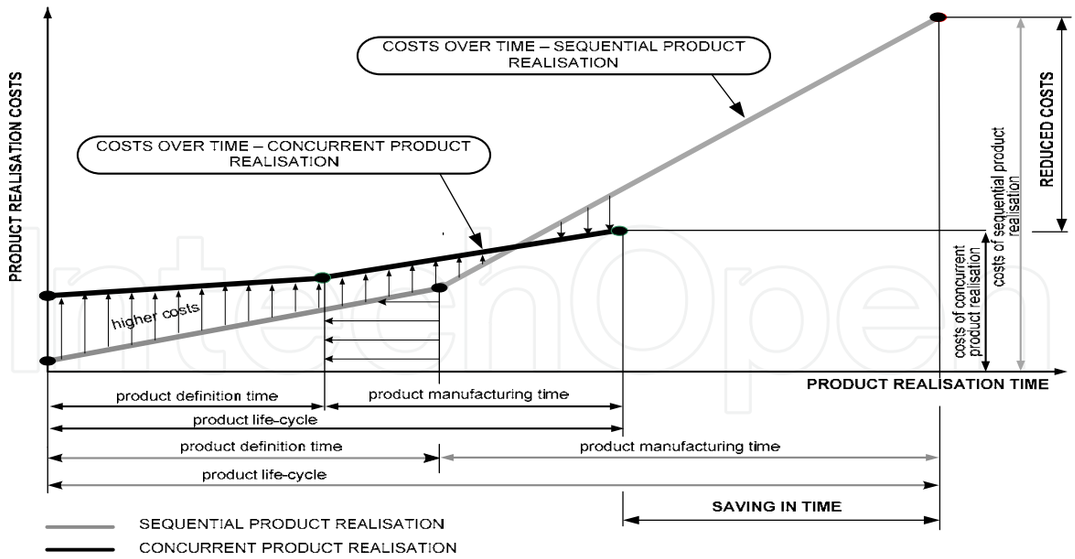

Fig. 1. Time and costs of sequential and concurrent product realisation

The cost of product definition is much higher in concurrent product realisation, due to the parallel execution of activities (more work is done during this stage), while production costs are much lower than in sequential realisation, due to short iteration loops for carrying out changes and eliminating errors.

In concurrent product realisation, there are interactions between individual stages of the product realisation process. Track-and-loop technology has been developed for executing these interactions (Prasad, 1996; Dickman, 2009). The type of loop defines the type of co-operation between overlapping stages of the concurrent product realisation process. Winner (Winner et al., 1988) suggests that 3-T loops should be used where interactions exist between three levels of a concurrent product realisation process).

A transformation of input into output is made in every loop, on the basis of requirements and restrictions (Prasad, 1996) as it is shown in the information flow diagram in the track-and-loop process of concurrent product realisation (Kušar et al., 2004).

In small companies, a two-level team structure is planned for execution of 3-T loops of a concurrent product realisation process with a variable structure of core and project teams (Duhovnik et al. 2001; Rihar et al., 2010). The task of the core team is process support and control, while the task of (virtual) project teams is execution of the tasks defined within the concurrent product realisation process.

It is obvious that concurrent product realisation is not possible without well-organised teamwork or virtual teamwork, which is the means for organisation integration. It incorporates:

- the formation of a core team, project teams or virtual project teams in product realisation loops,
- the selection of communication tools for the core team, project teams or virtual project teams,
- the definition of a communication matrix.

2. Teamwork in concurrent product realisation

Teamwork is a precondition for transition to concurrent product realisation.

2.1 Forming teams or virtual teams for concurrent product realisation

Analysis of teams in small companies (Figure 2) led the employees of the LAPS laboratory at the Faculty of Mechanical Engineering in Ljubljana, Slovenia, to the conclusion that concurrent product realisation required a shift from the terms "team" and "teamwork" to "virtual team" and "virtual teamwork" (Rad & Levin, 2003; Duhovnik et al., 2009; Köster, 2010) when forming project teams.

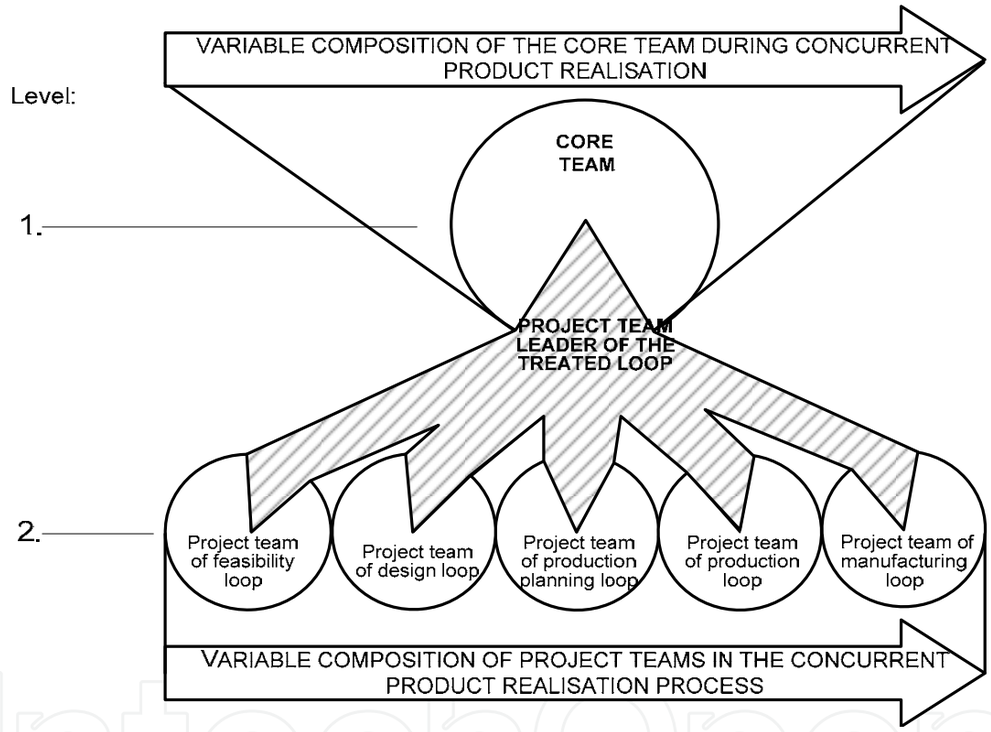

Fig. 2. Two-level team structure in the track and loop process of concurrent product realisation

A team is defined as a small group of people with complementary abilities that are activated in order to achieve the common goal for which they are all responsible. Team members are at the same location, in the same room.

A virtual team is defined as a team consisting of members that are located in various buildings, countries or states and their cooperation is not limited by distance, organisation or national borders. Virtual teams are formed to carry out a specific project. The teams are disbanded when the project is finished.

A geographically dispersed virtual team allows a company to select the best team members, regardless of their locations. There is also a substantial saving in time and costs of virtual

team operation. Moreover, a virtual team can often have short meetings (if needed), which is physically difficult to achieve with a "classical" team.

Experience in solving problems related to forming teams or virtual teams (Kušar et al., 2008; Žargi et al., 2009; Palčič et al., 2010) led the laboratory researchers to the conclusion that a virtual team should be formed in the following steps:

Step 1: Identifying the need for a virtual team

Globalisation, global competition and rapid market changes require high-quality information to be relevant and cheap. If a company does not have the required experts in its proximity, it has to form virtual team(s) for concurrent product realisation.

Step 2: Definition of virtual team tasks

Virtual team tasks must be clearly defined, with task execution processes described in detail. All virtual team members must understand their tasks, roles and responsibilities in the same way. The goals of the virtual team must be clearly defined and accepted by all members of the virtual team.

Step 3: Definition of procedures and processes for achieving the common goal

Operative procedures and processes that will ensure perfect operation of the virtual team must be developed and implemented in a virtual team. Members of the virtual team must understand how and in what sequence the concurrent product realisation tasks will be executed.

Step 4: Selection of virtual team members

In this step, it is necessary to decide what types of expert knowledge are required for successful execution of activities in the loops of product realisation, and which experts would be best for performing these activities. The selected members of a virtual team should be able to work efficiently in a virtual environment with the aid of ITC infrastructure for virtual team operation.

Step 5: Appointment of a virtual team leader

The success of a virtual team leader depends on his skills, tools, techniques and strategies in a virtual environment. Because of many different forms of expert knowledge and leadership abilities, it is possible to rotate the virtual team leader—various members of a virtual team can undertake the role of team leader at various stages of the product realisation process.

2.2 Communication tools used in teams and virtual teams for concurrent product realisation

Members of (virtual) teams must constantly communicate in order successfully to perform their tasks and to achieve the common goal. This is possible by using the available hardware and software (Duarte & Snyder, 2006).

Hardware includes telephones, modems and communication links (Internet connections). These are used for data transfer and for video conferences. Software includes efficient programs, LAN, communication and other tools for holding meetings.

It is possible to achieve efficient communication between members of the core team and virtual project teams by using the Internet. Several Internet-based communication tools exist for efficient communication among team members.

Team meeting

The most common and efficient type of communication is a team meeting. The team leader calls a meeting and sends the agenda, required material and proposals for decisions.

The team members gather at the agreed time in the appointed room, which should be quiet, pleasant and fitted with audio- and video equipment.

The team leader or moderator chairs the meeting. Team members deal with the problems in accordance with the agenda and, as a rule, conclusions are adopted unanimously. During the meeting, a record is kept and the minutes are sent to all team members after the meeting.

Team members know each other well, which contributes to establishing good relations and trust within the team.

It is possible to improve the efficiency of meetings by using methods of creative search and evaluation of ideas (Scheer, 2007).

Video conference

If the team members are in the same room, when they create a document, they gather around a PC. If they are at different locations but connected by the Internet, they need a tool for bi-directional video and audio transfer—this is a video conference.

If a video conference is held via the Internet, a high performance PC, additional equipment for high-quality video and audio processing and a high-speed Internet connection to the distant system (the other point of the video conference) are required.

A video camera is used for filming, with its results shown on a monitor; sound cards and microphones process audio signals and loudspeakers reproduce the sound.

A video conference can be organised in several different ways:

- a video conference between two users (full-duplex transfer of audio and video signals),
- a video conference between a single user on one side and several users on the other (full-duplex distributed transfer of audio and video signals across the network),
- a video conference between several users, in which video and audio signals are transmitted from more than two locations, but they are displayed on one monitor at a time only (half-duplex mode).

Figure 3 shows the principle of video conference organisation.

In order to use video conference equipment via the Internet with anybody connected to the Internet anywhere, it is necessary to use standard equipment. The H.323 standard defines protocols for video conference communications via the Internet. All video conference equipment should therefore be compatible with the H.323 standard.

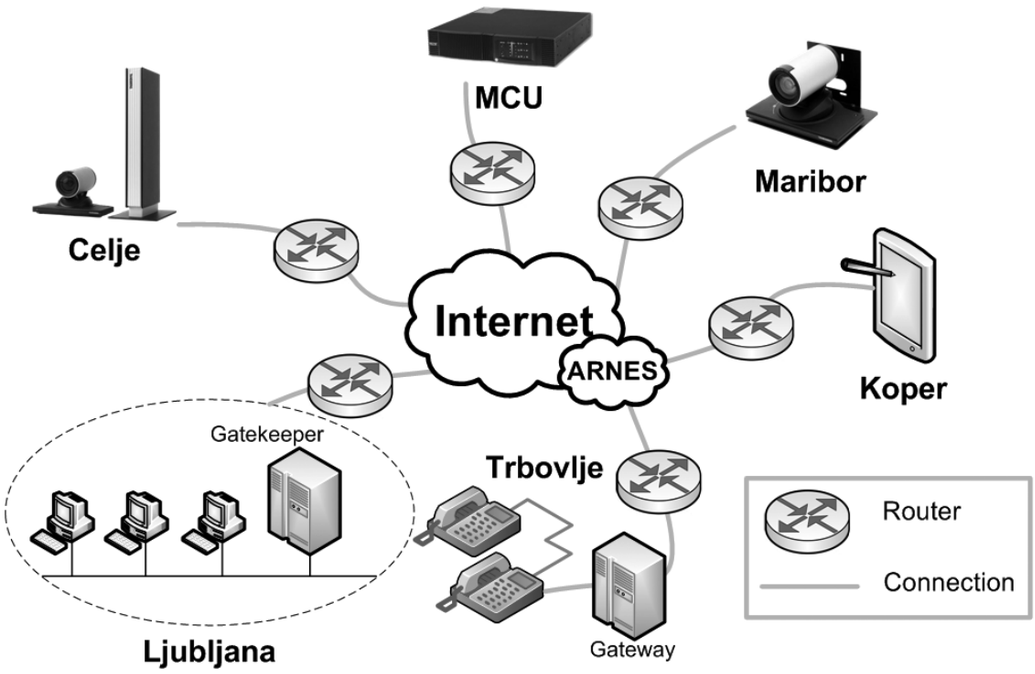

Fig. 3. Video conference

Audio conference

An audio conference is similar to a video conference, but without video transfer. The purpose of an audio conference is to hold an electronic meeting of two or more virtual team members at different locations.

The following hardware is required for an audio conference:

- a gateway server connects PBXs to the conference bridge,
- PCs or PBXs are connected to the server via the Internet,
- fixed line or mobile phones.

Software for audio conferences is based on LAN and WAN Internet communications, as well as IP and VOIP technologies. During an audio conference, the caller makes a connection from a PC or PBX (which connects stationary and mobile phones) via a VOIP output to the Internet. A gateway server enables connection with other audio conference participants.

A user can join the audio conference system by entering a password (PIN code). Figure 4 shows the principle of audio conference organisation.

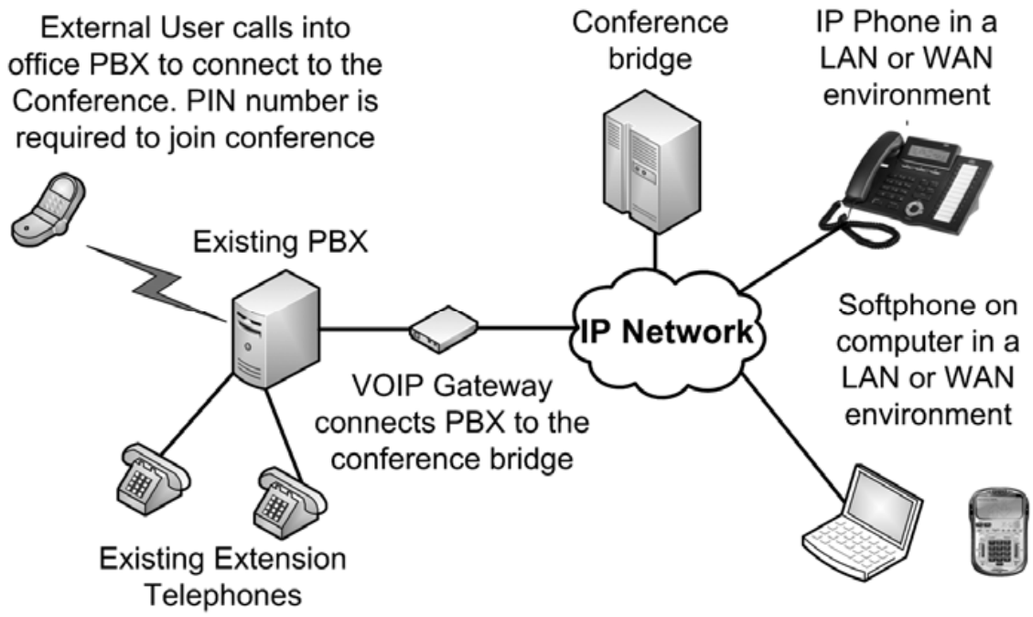

Fig. 4. Audio conference

Voice mail

Voice mail is used for the transmission of short voice messages between virtual team members. It is often used in combination with phone communications. If a virtual team member is not accessible by phone, the caller can leave him a short message.

E-mail

E-mail allows the transmission of voice, pictures and text documents in electronic format (paper documents can also be converted to electronic format). E-mail increases team communication capacities.

An e-mail system consists of two servers:

- an SMTP server for sending outgoing messages,
- a POP3 or IMAP server for the transmission of incoming messages.

An e-mail consists of a short message text and attached documents (files). The problem with e-mail is that messages can get lost or the server on the recipient side can decide that they are spam and delete them. Another problem may be a vast number of e-mail messages, so the recipient spends a lot of time reading and answering. E-mails are often integrated with central web data warehouses that allow traceability and access to messages. Figure 5 shows the principle of organising an e-mail system with a data warehouse.

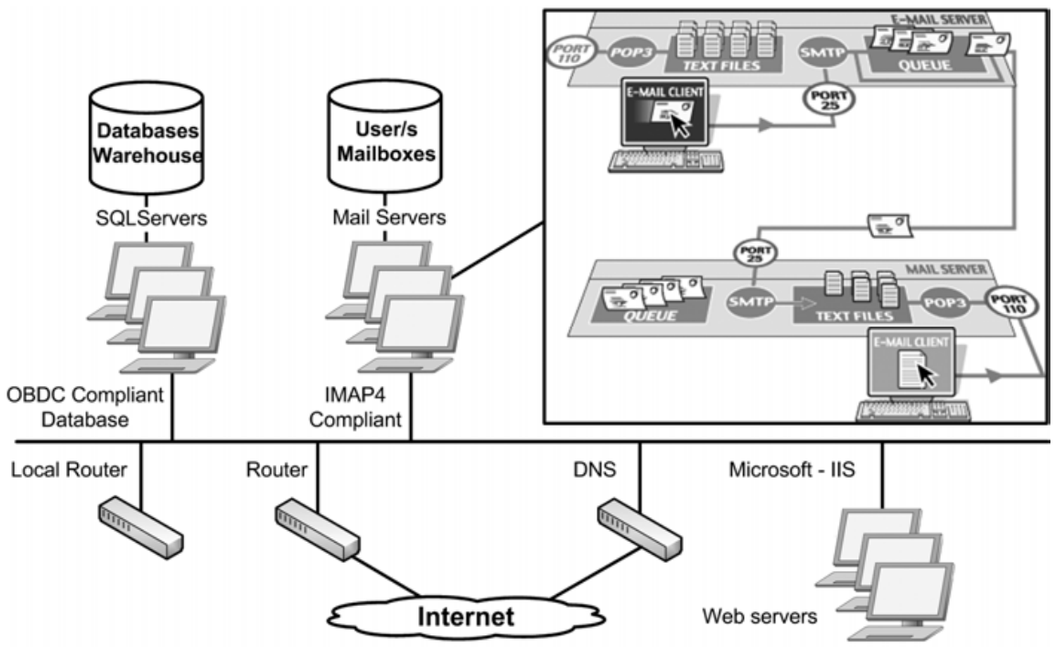

Fig. 5. E-mail system with data warehouse

Groupware

Groupware is a universal system for joining virtual team members and can be used anytime and anywhere. Groupware tools allow simple, rapid, reliable and cheap communication among virtual team members without any limitations. An example of groupware use is given in Figure 6.

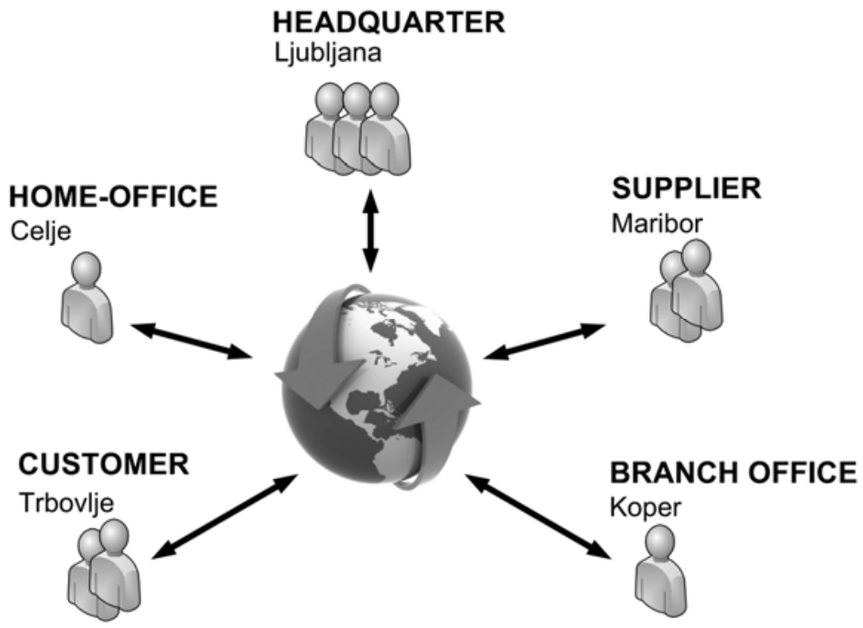

Fig. 6. Groupware

Groupware tools can be used to create a virtual office, which allows creative teamwork, supported by the Internet and World Wide Web. The creation of a virtual office with groupware is shown in Figure 7.

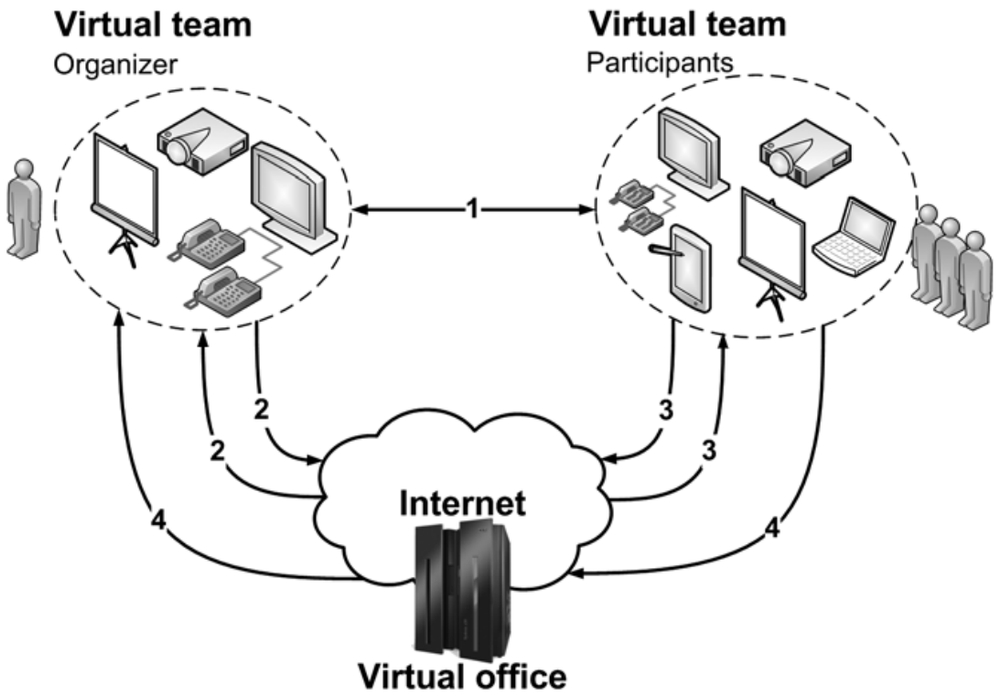

Fig. 7. Creation of a virtual office with groupware

Steps in the creation of a virtual office:

Step 1: The virtual team leader establishes contacts with other virtual team members, e.g. by e-mail.
Step 2: The virtual team leader defines the communication process in the Internet environment, which represents a virtual office.
Step 3: Other virtual team members log into the virtual office using their passwords.
Step 4: Cooperation and exchange of information among virtual team members is performed only via the virtual office.

Electronic white board

An electronic white board is a combination of hardware and software tools that serve as a support to team meetings. It can be portable or fixed. It allows writing and drawing during a team meeting. The text on the white board can be stored in electronic format and sent via communication channels to other virtual team members, e.g., during a video conference or groupware use.

2.3 Advantages and drawbacks of communication tools

The research group at the Laboratory for Manufacturing Systems at the Faculty of Mechanical Engineering in Ljubljana, Slovenia, decided to analyse the characteristics,

advantages and drawbacks of communication tools required in (virtual) teamwork of concurrent product realisation.

On the basis of collected and verified data from vendors of (virtual) teamwork communication tools, every team member made a list of the features, advantages and drawbacks of these tools. The team leader then organized a creativity workshop to obtain a coordinated proposal of the features, advantages and drawbacks of available communication tools. The results of the creativity workshop are shown in Table 1.

Communication tool	**Features**	**Advantages**	**Drawbacks**
TEAM MEETING on one location Suitable for: TEAMWORK	- Best tool for real-time communication because of personal contact and visual & verbal communication between team members. - Meetings can be formal or informal.	- Visual and verbal communication. - Personal contacts between team members. - All team members know each other. - Participants can prepare for a meeting.	- All team members must have time to attend the meeting. - Much time needed for travel. - High travel costs.
VIDEO CONFERENCE Suitable for: VIRTUAL TEAM	- Good tool for real-time communication because of visual and verbal communication and possibility of interactions between team members. - No direct personal contacts between team members.	- Visual and verbal communication. - Indirect personal contact. - Prompt communication. - No expensive travel. - Saving in time. - Team members can prepare for a meeting if they know its purpose and agenda in advance. - The use of audio/video equipment.	- All team members must be in the video conference room at the same time. - Preparation in advance is required. - Time delay of video due to distance. - High costs of hiring communication channels.
AUDIO CONFERENCE Suitable for: VIRTUAL TEAM	- Good tool for real-time communication. - Verbal communication and possibility of interactions between team members. - Functions in the Internet environment.	- Reliable and always available communication tool. - Participants are on various locations. - Participants only need the Internet connection. - Low cost of use.	- Only verbal communication. - Participants must be simultaneously present in the communication network.
VOICE MAIL Suitable for: VIRTUAL TEAM	- Tool for impersonal communication. - For urgent messages only.	- Message is sent to the recipient regardless of his presence. - Recipient has time to prepare an answer.	- Impersonal communication. - Suitable for urgent, short messages.
E-MAIL Suitable for: VIRTUAL TEAM	- Impersonal communication without visual and verbal communication. - No interactions between team members.	- Useful for sending text messages and documents. - Return receipt.	- Impersonal communication. - Limited size of documents to be sent.

Communication tool	Features	Advantages	Drawbacks
GROUPWARE Suitable for: VIRTUAL TEAM	- Allows verbal communication between team members. - Exchange if information in real-time. - Simultaneous communication between several team members. - During task execution the system allows simultaneous work of several participants on various locations. - Common databases. - Communication process must be defined in advance.	- Simultaneous cooperation of team participants on various locations. - Concurrent exchange of data and information. - Access to data on a common server. - Video communication is possible with additional video equipment. - Information can be sent to team members via voice mail.	- High burden for computer communications. - High data-transmission costs.
ELECTRONIC WHITE BOARD Suitable for: TEAMWORK and VIRTUAL TEAM	- Portable or fixed board that allows electronic data acquisition, exchange and archiving.	- Simple use. - Intended for taking notes on results. - Rapid electronic transfer of the board contents to other team members.	- High investment cost - Expensive and complicated maintenance.

Table 1. Advantages and drawbacks of tools for (virtual) teamwork

It can be seen from Table 1 that only two types of communication tools are suitable for teamwork (team meeting and electronic white board), while other tools are suitable for virtual teamwork.

Analysis of several examples of virtual teamwork showed that virtual teamwork is successful if four organisational roles are filled in the team:

Role 1: Convener of the virtual team meeting (defines goals, expected results and specifies the agenda).
Role 2: Technical assistant (prepares the meeting, tests the operation of the communication tools before the meeting and ensures flawless operation during the meeting).
Role 3: Virtual team leader (ensures the successful work of the virtual team by explaining specific questions).
Role 4: Other virtual team members (prepare themselves for the meeting and participate actively during the meeting).

2.4 Communication matrix in product realisation loops

The communication matrix defines the method of exchanging information and documents in the execution of concurrent product realisation activity loops. A list (Table 2) must be made for every activity:

- input information with required documents for beginning execution of the activity,
- output information with required documents that arise from execution of the activity,
- tools for creating and storing information,
- sender of the information or document,
- receiver of the information or document,
- communication tool used for information exchange.

ID	*Input information–document*	*Activity*	*Output information–document*	*Tools used*	*Information (document) sent by*	*Information (document) received by*	*Communication tool*
1	Input information of activity 1	ACTIVITY 1	Output information of activity 1	...	Sender 1	Receiver 1.	Tool 1
2	...	...	...	...	...	...	...
3	...	...	...	...	...	...	...
4	...	...	...	...	...	...	...
n	Input information of activity n	ACTIVITY n	Output information of activity n		Sender n	Receiver n.	Tool n

Table 2. Communication matrix in concurrent product realisation loops

3. Concurrent realisation of a pedal assembly

A company decided to make a project plan for concurrent realisation of a pedal assembly and to carry out this project (Figure 8).

Fig. 8. Pedal assembly

The goal of the project was to make a competitive pedal assembly, suitable in terms of quality, reliability, mass, price and realisation time. Concurrent realisation of the pedal assembly was divided into six stages:

Stage 1: Preparation of the pedal assembly realisation project,
Stage 2: Development of the pedal assembly,
Stage 3: Development of the pedal assembly realisation process,
Stage 4: Test production of pedal assembly,
Stage 5: Qualification of the pedal assembly realisation process,
Stage 6: Regular production of the pedal assembly.

There were 280 activities and five loops of concurrent realisation of the pedal assembly within the six stages of pedal assembly realisation:

1. Order acquisition loop (3-T loop),
2. Pedal assembly development loop (3-T loop),
3. Pedal assembly process loop (3-T loop),
4. Pedal assembly qualification loop (3-T loop),
5. Completion of the project of pedal assembly realisation loop (2-T loop).

Figure 9 shows how the loops are formed, and the type of cooperation within realisation stages.

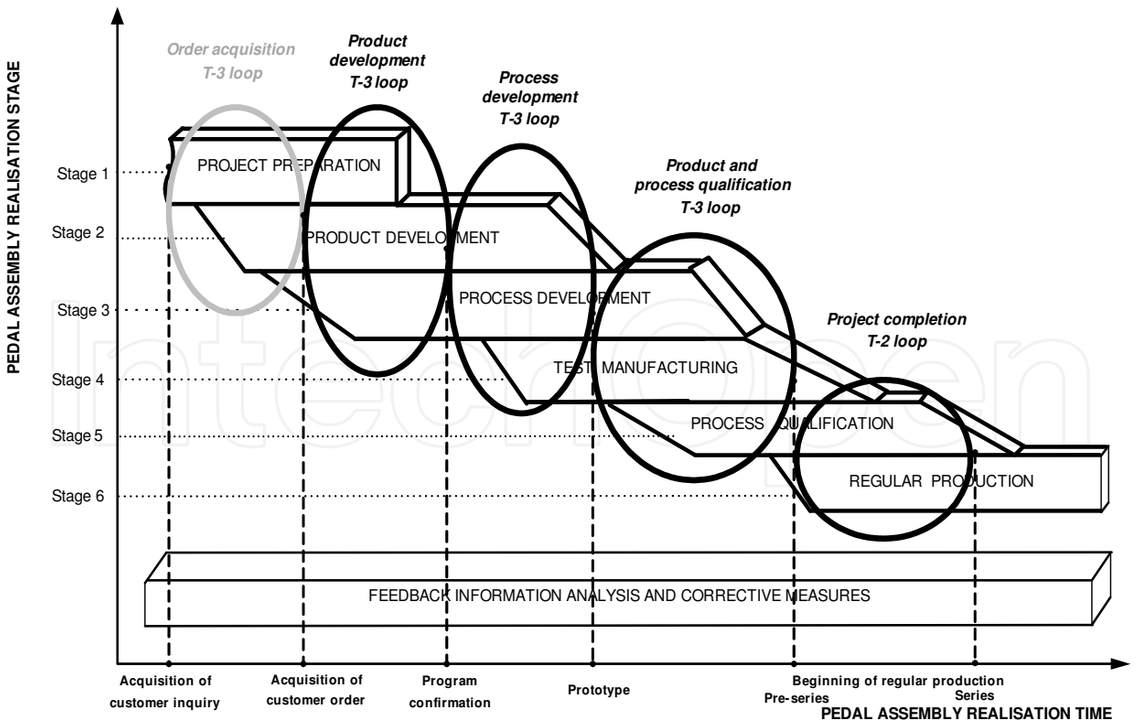

Fig. 9. Loops of concurrent realisation of pedal assembly

3.1 Forming teams / virtual teams for realisation of pedal assembly

After seeing the presentation of two- and three-level structures of (virtual) teams in product realisation loops (Duhovnik et al., 2001; Kušar et al., 2004) the company management selected a two-level team structure, whereby the core team is on the first level and five virtual project teams are on the second level (Figure 10).

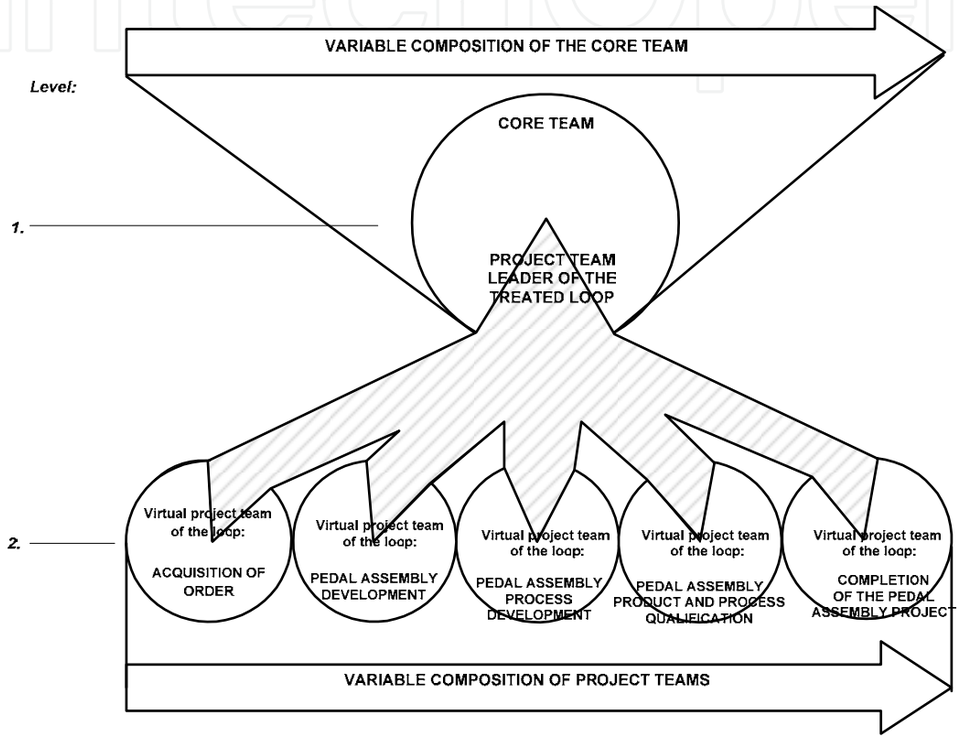

Fig. 10. Structure of teams for concurrent realisation of pedal assembly

Forming the core team

The core team for concurrent realisation of the pedal assembly will monitor the whole project, solve organisational issues and coordinate the strategy of performing tasks. The company management decided that the following people would be members of the core team:

- project manager (PM) — permanent member,
- project team leader of a particular loop (VPL) — non-permanent member,
- head of supply department (external supply and sales of investment funds — PUR+SIF) — permanent member,
- head of sales and sales logistics department (S+LD) — permanent member,
- head of development department (DEV) — permanent member,

- head of industrialisation and development of manufacturing technology department (IND+MTD) – permanent member,
- head of manufacturing planning and supply, maintenance and manufacturing centre (MP+MNT+MC) – permanent member,
- head of quality control department (Q) – permanent member,
- head of suppliers (SUP) – permanent member,
- head of customers (CUS) – permanent member.

Figure 11 shows the structure of the core team for concurrent realisation of the pedal assembly.

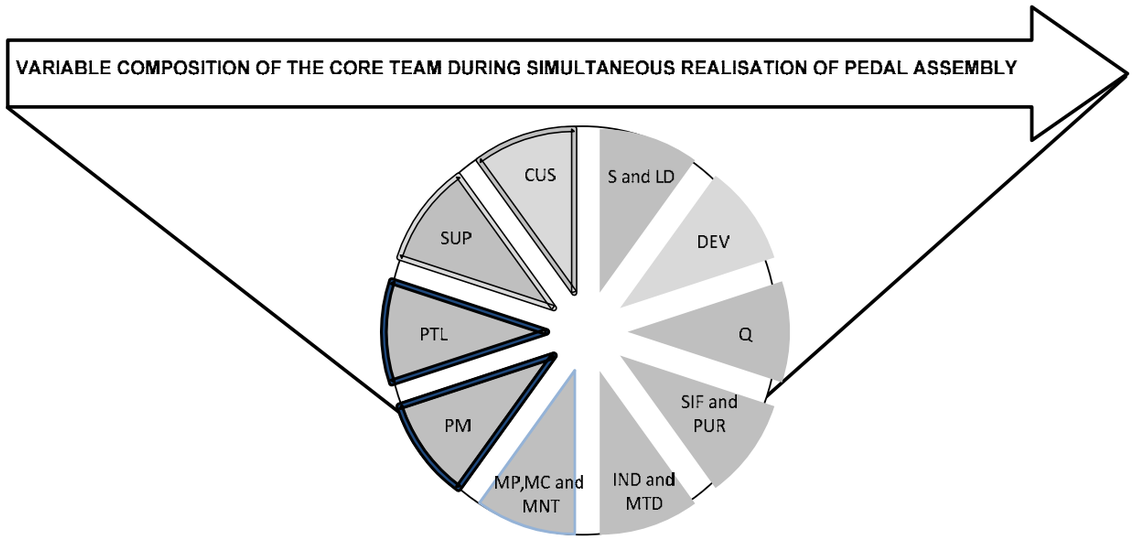

Fig. 11. Core team structure

Core team members (with the exception of the project manager) will work on the project part of their working time and the rest of the time they will perform tasks in their departments. The project team manager will be outside his department throughout the project duration and will work full time on the project. When the project is finished the project team manager will return to his department.

Forming virtual project teams for the loops of concurrent realisation of the pedal assembly

As shown in Figure 10, there will be five virtual project teams in loops of concurrent realisation of the pedal assembly. Members of virtual teams will be experts from 14 company departments and two representatives from strategic suppliers and customers, depending on the level of assigned responsibility for execution of activities within a particular loop. Figure 12 presents a Gantt chart of the first loop of concurrent realisation of the pedal assembly: "Order acquisition loop".

Intensity of responsibility of virtual team members during execution of loops of concurrent realisation of pedal assembly	**POINTS**
Member is informed	1
Member participates	3
Member has responsibility	9

Table 3. Intensity of responsibility of virtual team members

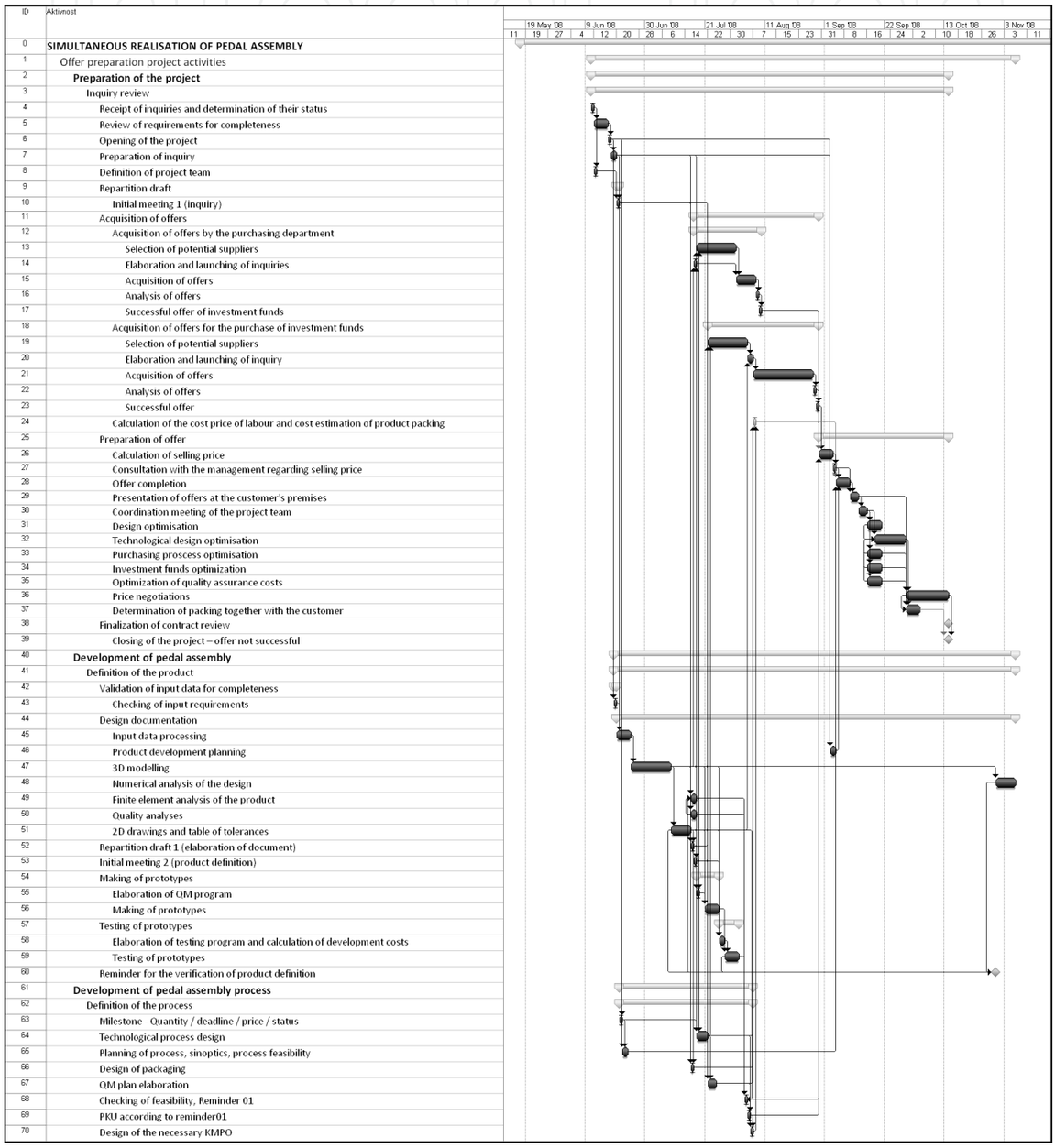

Fig. 12. Gantt chart of the "Order acquisition loop"

When the company obtains an offer, loop 1 activities (Order acquisition loop) are started; its three stages are: project preparation, development of the pedal assembly and development of the pedal assembly process. This loop is executed when the sales department considers that it is sensible to make an offer for the realisation of the pedal assembly.

Loop 1 is followed by loops 2, 3, 4 and 5. The project manager decided (in agreement with the company management) that the intensity of responsibility of each virtual team member during the execution of activities would be marked by a 1-3-9 method, as shown in Table 3.

A creativity workshop was organised with 14 representatives from company departments, as well as representatives from suppliers and customers. The goal of the workshop was to score the intensity of responsibility of virtual team members when executing the activities of the five loops in concurrent realisation of the pedal assembly.

The results of scoring the intensity of responsibility of virtual team members during execution of the first loop of concurrent realisation of the pedal assembly are presented in Table 4.

It can be seen from the Table 4 what are the responsibilities of each virtual team member for the execution of activities in the first loop of pedal assembly realisation.

The procedure of scoring the intensity of responsibility of virtual team members was also carried out for the other loops.

From the sum of points assigned to the i-th team member during execution of activity in the j-th loop, a factor of total intensity of responsibility of the i-th member in the j-th loop can be calculated as:

$$FTI_{ij} = \frac{SMP_{ij}}{SAP_j} \tag{1}$$

FTI_{ij} factor of total intensity of responsibility of the i-th team member in the j-th loop
SMP_{ij} sum of the points assigned to the i-th member in the j-th loop
SAP_j sum of all points assigned in the j-th loop

The results of the calculation of the total intensity of responsibility factor of virtual project team members during execution of activities in all five loops of concurrent realisation of pedal assembly are shown in Table 5.

After they had made an overview of the total intensity of responsibility factors of virtual team members during execution of activities in the loops of pedal assembly realisation, the creativity workshop participants reached the following conclusions:

- the i-th member of the virtual project team (VPT) of the j-th loop of realisation of the pedal assembly, with the maximum factor of total intensity of responsibility, would be appointed as team leader of the j-th loop of PTL,
- representatives from departments with a total intensity of responsibility factor above 5% would also be included in the j-th loop of pedal assembly realisation,
- representatives of suppliers and customers would also be included in the j-th loop of pedal assembly realisation, regardless of their total intensity of responsibility factor, in order to avoid misunderstanding suppliers' and customers' requirements.

ID	Name	1. MNG	2.S	3.PM	4.DEV	5.IND	6.Q	7.MTD	8.SIF	9.PUR	10.MC	11.MP	12.MNT	13.AD	14.LD	15.SUP	16.CUS
0	**SIMULTANEOUS REALISATION OF PEDAL ASSEMBLY**																
1	**Offer preparation project activities**																
2	**Preparation of the project**																
3	**Inquiry review**																
4	Receipt of inquiries and determination of their status		9														3
5	Review of requirements for completeness		9		3												
6	Opening of the project		9	1	1	1	1		1	1					1		
7	Preparation of inquiry		9	1	1	1	1		1	1					1		
8	Definition of project team		9	1	1	1	1		1	1					1		
9	Repartition draft																
10	Initial meeting 1 (inquiry)		9	3	3	3	3		3	3					3		
11	**Acquisition of offers**																
12	**Acquisition of offers by the purchasing department**																
13	Selection of potential suppliers									9						1	
14	Elaboration and launching of inquiries									9							
15	Acquisition of offers									9							
16	Analysis of offers									9							
17	Successful offer of investment funds									9						1	
18	**Acquisition of offers for the purchase of investment funds**																
19	Selection of potential suppliers								9								
20	Elaboration and launching of inquiry								9								
21	Acquisition of offers								9								
22	Analysis of offers								9							1	
23	Successful offer								9							1	
24	Calculation of the cost price of labour and cost estimation of product		1			9	1		1	3		1			1	1	3
25	**Preparation of offer**																
26	Calculation of selling price		9	3							3						
27	Consultation with the management regarding selling price	3	9														
28	Offer completion		9			5											
29	Presentation of offers at the customer's premises		9		3	3	3										3
30	Coordination meeting of the project team		9	3	3	3	3		3	3	3						
31	Design optimisation		3		9	3	3		3	3							
32	Technological design optimisation		3			9	3		1	1							
33	Purchasing proscess optimisation		3							9							
34	Investment funds optimization		3						9								
35	Optimization of quality assurance costs		3			3	9		3								
36	Price negotiations		9		3												3
37	Determination of packing together with the customer		9		3												3
38	**Finalization of contract review**																
39	Closing of the project – offer not successful		9	1	1	1	1		1	1		1			1		
40	**Development of pedal assembly**																
41	**Definition of the product**																
42	**Validation of input data for completeness**																
43	Checking of input requirements				9	9											
44	**Design documentation**																
45	Input data processing				9												
46	Product development planning		3		9	3											
47	3D modelling				9												
48	Numerical analysis of the design				9												
49	Finite element analysis of the product				9	3	3	9	3	3	3					3	
50	Quality analyses				9												
51	2D drawings and table of tolerances				9												
52	Repartition draft 1 (elaboration of document)		3	3	9	1	1		1	1					1		
53	Initial meeting 2 (product definition)		9		9	3	3		3	3		3					
54	**Making of prototypes**																
55	Elaboration of QM program				9	1	1										
56	Making of prototypes				9	1	1										
57	**Testing of prototypes**																
58	Elaboration of testing program and calculation of development costs		1		9	1											
59	Testing of prototypes				9												
60	Reminder for the verification of product definition				9												
61	**Development of pedal assembly process**																
62	**Definition of the process**																
63	Milestone - Quantity / deadline / price / status		3	3													9
64	Technological process design					9											
65	Planning of process, sinoptics, process feasibility				3	9	3		3	3		3					
66	Design of packaging		1			3	1		1	3		1			1	1	3
67	QM plan elaboration				3		9										
68	Checking of feasibility, Reminder 01					9											
69	PKU according to reminder01		1			3	1		1	3		1			1	1	3
70	Design of the necessary KMPO					3	9										
71	Izvedbeni del projekta																
270	Redna proizvodnja																
278	ZAKLJUČEK PROJEKTA		1			9	1		1	3		1			1	1	3
282	**SUM**	**3**	**165**	**19**	**163**	**104**	**61**	**9**	**84**	**87**	**9**	**10**	**0**	**0**	**11**	**10**	**30**

LEGEND:

1	MNG – Management	5	IND – Industrialisation department	9	PUR – Supply department	13	AD – Accounting department
2	S – Sales department	6	Q – Quality control department	10	MC – Manufacturing centre	14	LD– Sales logistics department
3	PM – Project manager	7	MTD – Manufacturing technology development department	11	MP – Manufacturing planning and supply department	15	SUP– Suppliers
4	DEV – Development department	8	SIF – Investment funds supply department	12	MNT – Maintenance department	16	CUS – Customer

Table 4. Scoring the intensity of responsibility of virtual team members in the "Order acquisition loop"

Figure 13 presents the structure of virtual project teams of five loops in concurrent realisation of the pedal assembly.

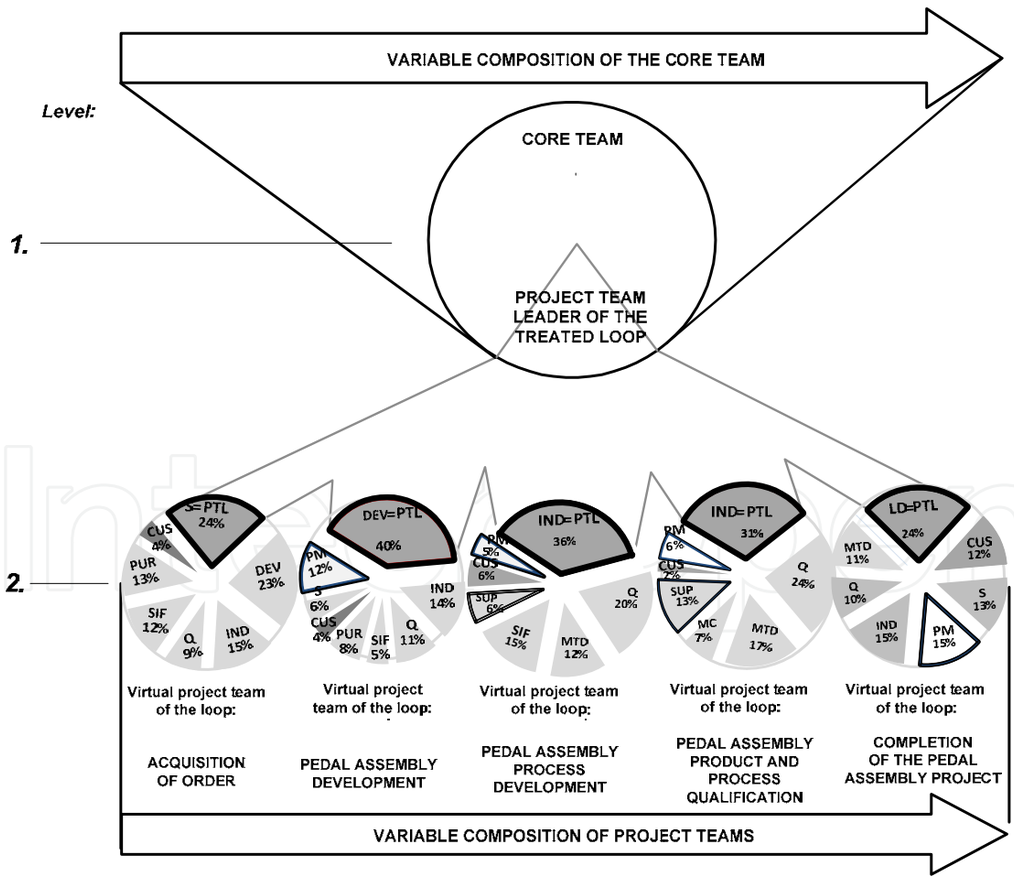

Fig. 13. Virtual project teams in the loops of concurrent realisation of the pedal assembly

REALISATION OF PEDAL ASSEMBLY LOOPS	*VIRTUAL TEAM MEMBERS*	*MNG*	*S*	*PM*	*DEV*	*IND*	*Q*	*MTD*	*SIF*	*PUR*	*MC*	*MP*	*MNT*	*AD*	*LD*	*SUP*	*CUS*	*SUM*
Loop 1: PREPARATION OF ORDER	*SCORING OF INDIVIDUAL TEAM MEMBERS IN LOOP 1*	3	165	19	163	104	61	9	84	87	9	10	0	0	11	10	30	*765*
	Intensity factor of individual team member	0.39	21.5	2.48	21.3	13.6	7.97	1.19	11.2	11.5	1.19	1.33	0	0	1.46	1.33	3.98	*100*
	SELECTED TEAM MEMBERS IN LOOP 1		165		163	104	61		84	87							30	*694*
	Intensity factor of the selected team member	0	23.8		23.4	14.9	8.79		12.1	12.5							4.32	*100*
Loop 2: DEVELOPMENT OF PEDAL ASSEMBLY	*SCORING OF INDIVIDUAL TEAM MEMBERS IN LOOP 2*	13	39	85	279	102	74	18	38	57	7	13	7	8	13	15	27	795
	Intensity factor of individual team member	1.7	5.2	11.3	37.2	13.6	9.9	2.4	5.1	7.6	0.9	1.7	0.9	1.1	1.7	2.0	3.6	***100***
	SELECTED TEAM MEMBERS IN LOOP 2		39	85	279	102	74		38	57							27	***701***
	Intensity factor of the selected team member		5.9	12.8	39.8	15.3	11.1		5.7	8.1							3.9	***100***
Loop 3: DEVELOPMENT OF PEDAL ASSEMBLY PROCESS	*SCORING OF INDIVIDUAL TEAM MEMBERS IN LOOP 3*	2	7	37	32	299	166	100	121	26	46	23	39	0	4	52	48	***1002***
	Intensity factor of individual team member	0.21	0.74	3.91	3.38	31.6	17.5	10.5	12.7	2.74	4.86	2.43	4.12	0	0.42	5.49	5.07	***100***
	SELECTED TEAM MEMBERS IN LOOP 3			37		299	166	100	121							52	48	***823***
	Intensity factor of the selected team member			4.82		38.9	21.6	13.1	15.8							6.78	6.23	***100***

REALISATION OF PEDAL ASSEMBLY LOOPS	VIRTUAL TEAM MEMBERS	MNG	S	PM	DEV	IND	Q	MTD	SIF	PUR	MC	MP	MNT	AD	LD	SUP	CUS	SUM
Loop 4: QUALIFI-CATION OF PEDAL ASSEMBLY AND PROCESSES	*SCORING OF INDIVIDUAL TEAM MEMBERS IN LOOP 4*		4	36	12	189	147	103	34	12	45	30	18	5	6	77	12	***730***
	Intensity factor of individual team member		0.5	4.9	1.6	25.9	20.	14.1	4.7	1.6	6.2	4.1	2.5	0.7	0.8	10.5	1.6	***100***
	SELECTED TEAM MEMBERS IN LOOP 4			36		189	147	103			45					77	12	***609***
	Intensity factor of the selected team member			5.9		31	24.1	16.9			7.4					12.6	2	***100***
Loop 5: COMPLE-TION OF THE PROJECT	*SCORING OF INDIVIDUAL TEAM MEMBERS IN LOOP 5*	20	43	48	7	49	32	37	2	12	18	14	4	21	80	6	39	***434***
	Intensity factor of individual team member	5.13	11.1	12.3	1.79	12.6	8.20	9.49	0.51	3.07	4.9	3.59	1.03	5.38	20.5	1.54	10	***100***
	SELECTED TEAM MEMBERS IN LOOP 5		43	48		49	32	37							80		39	***328***
	Intensity factor of the selected team member		13.1	14.6		14.9	9.76	11.3							24.4		11.9	***100***

Table 5. Factors of total intensity of responsibility of virtual project team members during execution of loops of pedal assembly realisation

ID	INPUT INFORMATION – DOCUMENT	*ACTIVITY*	OUTPUT INFORMATION – DOCUMENT	*TOOLS USED DURING EXECUTION OF ACTIVITY*	*INFORMATION (DOCUMENT) SENT BY*	*INFORMATION (DOCUMENT) RECEIVED BY*	*COMMUNI-CATION TOOL*
0	***CONCURRENT REALISATION OF PEDAL ASSEMBLY***						
1	***Offer preparation project activities***						
2	***Preparation of the project***						
3	***Inquiry review***						
4	Inquiry	***Receipt of inquiries and determination of their status***	PP document		CUSTOMER	P	e-mail
5	PP document	***Review of requirements for completeness***	Check of data (first sieve)		S		
6	Check of data (first sieve)	***Opening of the project***	Design of implementation project	SAP	S	All departments	
7	Design of implementation project	***Preparation of inquiry***	Message about opening of inquiry	SAP	S	All departments	e-mail; GW
8	PP document	***Definition of project team***	Decision about temporary project group		S	DEV, IND, PUR, Q, PM	e-mail; GW
9	***Repartition draft***						
10	Decision about temporary project group; Message about opening of inquiry	***Initial meeting 1 (inquiry)***	Minutes of the meeting about product draft, Repartition draft	S		DEV, IND, PUR, Q, PM	e-mail; GW
11	***Acquisition of offers***						
12	***Acquisition of offers by the purchasing department***						
13	3D model, customer requirements; 2D drawings; Repartition draft 1; Minutes of the meeting about product draft	***Selection of potential suppliers***	Selection of potential suppliers		PUR	SUP	e-mail

ID	INPUT INFORMATION – DOCUMENT	*ACTIVITY*	OUTPUT INFORMATION – DOCUMENT	*TOOLS USED DURING EXECUTION OF ACTIVITY*	*INFORMATION (DOCUMENT) SENT BY*	*INFORMATION (DOCUMENT) RECEIVED BY*	*COMMUNI-CATION TOOL*
14	Inquiry by the sales department; 3D model, customer requirements; Repartition draft 1	***Elaboration and launching of inquiries***	Inquiry by the sales department	P	UR S	UP. e	-mail
15	Offer of a supplier; Selection of potential suppliers	***Acquisition of offers***	Offer of a supplier	P	UR S	e	-mail
16	Offer of a supplier	***Analysis of offers***	Analysis of offers sent by a supplier	P	UR S	UP e	-mail
17	Analysis of offers sent by a supplier	***Successful offer of investment funds***	Selection of the supplier	P	UR S	UP A	C
18	***Acquisition of offers for the purchase of investment funds***						
19	List of bidders; 3D model, customer requirements; 2D drawings; Repartition draft 1, Technological process design	***Selection of potential suppliers***	Selection of suppliers		SIF		
20	Selection of suppliers; 2D drawings; Selection of suppliers	***Elaboration and launching of inquiry***	Inquiry		SIF	SUP	e-mail; GW
...	...	...	...	...	...	...	...
39	Confirmed product design; Confirmed product packaging	***Closing of the project – offer not successful***	Closing of the project		MANAGEME NT	S, All departments	e-mail; voice mail
40	***Development of pedal assembly***						
41	***Definition of the product***						
42	***Validation of input data for completeness***						
43	Design of implementation project	***Checking of input requirements (requirements book, inquiry)***	Reviewed input requirements and harmonised requirements with the contract	A			C

ID	INPUT INFORMATION – DOCUMENT	*ACTIVITY*	OUTPUT INFORMATION – DOCUMENT	*TOOLS USED DURING EXECUTION OF ACTIVITY*	*INFORMATION (DOCUMENT) SENT BY*	*INFORMATION (DOCUMENT) RECEIVED BY*	*COMMUNI-CATION TOOL*
44	***Design documentation***						
45	Message on opening of inquiry (customer requirements, environment)	***Input data processing***	Connection of SAP and ST data	ST	DEV		SAP; SMT
46	Design of implementation project; Message on opening of inquiry	***Product development planning***	Process development planning		DEV	Q, IND, PUR, SIF	SAP
47	Connection of SAP and SMT data	***3D modelling***	3D model, bill of materials	CATIA	DEV		SAP; SMT
…	...	...	...	...	...	...	. ..
60	Table of tolerances; Special requirements for a particular technology; 2D drawings; Test validation report; Report on final element analysis of the project, Important characteristics	***Reminder for the verification of product definition***	Reminder 00		IND	DEV, S	meeting
61	***Development of pedal assembly process***						
62	***Definition of the process***						
64	3D model, customer requirements; 2D drawings; Minutes of the meeting about product draft; Known required quantities, manufacturing deadlines and price	***Technological process design***	Technological process design		IND	DEV, Q, IND	SAP;SMT
65	Known required quantities, manufacturing deadlines and price; Message on opening of inquiry; Design of implementation project	***Process planning, synoptics, process feasibility***	Definition of plan, synoptics and process feasibility				SAP;SMT; e- mail

ID	INPUT INFORMATION – DOCUMENT	*ACTIVITY*	OUTPUT INFORMATION – DOCUMENT	*TOOLS USED DURING EXECUTION OF ACTIVITY*	*INFORMATION (DOCUMENT) SENT BY*	*INFORMATION (DOCUMENT) RECEIVED BY*	*COMMUNI-CATION TOOL*
66	Customer requirements regarding packaging; 3D model, customer requirements; 2D drawings	***Design of packaging***	Design of packaging		IND	S	SVP; EWB
67	3D model, customer requirements; Minutes of the meeting about product draft, Repartition draft; 2D drawings; Technological process design	***QM plan elaboration***	QM plan elaboration		IND	DEV,Q, IND-KALKULACIJA	SAP;SMT
68	Table of tolerances, Special requirements for a particular technology; 2D drawings; Test validation report	***Checking of feasibility, Reminder 01***	Reminder 01		IND	DEV,Q, IND	SAP; SMT; meeting
69	Reminder 01	***PKU according to reminder01***	PKU according to reminder01	I	ND, Q D	E V, IND m	e etirg
70	Technological process design; QM plan elaboration	***Design of the necessary KMPO***	Report on KMPO	I	ND, Q D	E V, IND	SAP;SMT, EWB

Legend of communication tools:

GW- groupware AC- audio conference SMT- smarteam EWB- electronic white board

Table 6. Communication matrix for execution of "Order acquisition loop" activities

3.2 Forming the communication matrix

A creativity workshop was organised with 14 representatives from company departments, as well as representatives from suppliers and customers. The goal of the workshop was to define for every activity in the loops of concurrent realisation of pedal assembly:

- input information with required documents for beginning execution of an individual activity,
- output information with required documents that arise from execution of an individual activity,
- tools for creation and storage of information,
- senders of information or documents,
- receivers of information or documents, and
- the mode of sending the information or documents.

Table 5 shows some results of the creativity workshop regarding the formation of the communication matrix for execution of activities of the "Order acquisition loop".

The communication matrix defines in advance the mode of information exchange and communication tools required.

4. Conclusion

The paper emphasises that concurrent product realisation is not possible without well-organised teamwork or virtual teamwork.

A two-level team structure of a track-and-loop process of concurrent product realisation, suitable for small companies, is presented. An overview is given of available communication tools for teamwork/virtual teamwork, with the advantages and drawbacks of individual tools. The content of the communication matrix of concurrent product realisation is formed, defining the exchange of information/documents in the execution of concurrent product realisation activity loops.

Special attention in this paper is given to the presentation of the methodology for design of concurrent engineering loops and to the determination of team members / virtual teams for concurrent product realisation process.

The core team members and the project team members determination are based on the calculation of total intensity factor of responsibility of the participants on the project of concurrent product and processes realisation (functional units of the company, customer, suppliers, subcontractors).

The suggested methodology of forming teams or virtual teams and communication matrix of concurrent product realisation was tested on a study case of a pedal assembly.

The project of pedal assembly is divided in five concurrent engineering loops. Member of the team / virtual team which has the maximal intensity factor leads the project team for concurrent engineering loop realisation (sales department leads the team for realisation of the first concurrent engineering loop).

Further work on solving concurrent product realisation problems will be focused on making a catalogue of the entire concurrent product realisation process using ARIS—a tool for process modelling and reengineering (Scheer, 1999).

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The book "New Technologies - Trends, Innovations and Research" presents contributions made by researchers from the entire world and from some modern fields of technology, serving as a valuable tool for scientists, researchers, graduate students and professionals. Some practical applications in particular areas are presented, offering the capability to solve problems resulted from economic needs and to perform specific functions. The book will make possible for scientists and engineers to get familiar with the ideas from researchers from some modern fields of activity. It will provide interesting examples of practical applications of knowledge, assist in the designing process, as well as bring changes to their research areas. A collection of techniques, that combine scientific resources, is provided to make necessary products with the desired quality criteria. Strong mathematical and scientific concepts were used in the applications. They meet the requirements of utility, usability and safety. Technological applications presented in the book have appropriate functions and they may be exploited with competitive advantages. The book has 17 chapters, covering the following subjects: manufacturing technologies, nanotechnologies, robotics, telecommunications, physics, dental medical technologies, smart homes, speech technologies, agriculture technologies and management.

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