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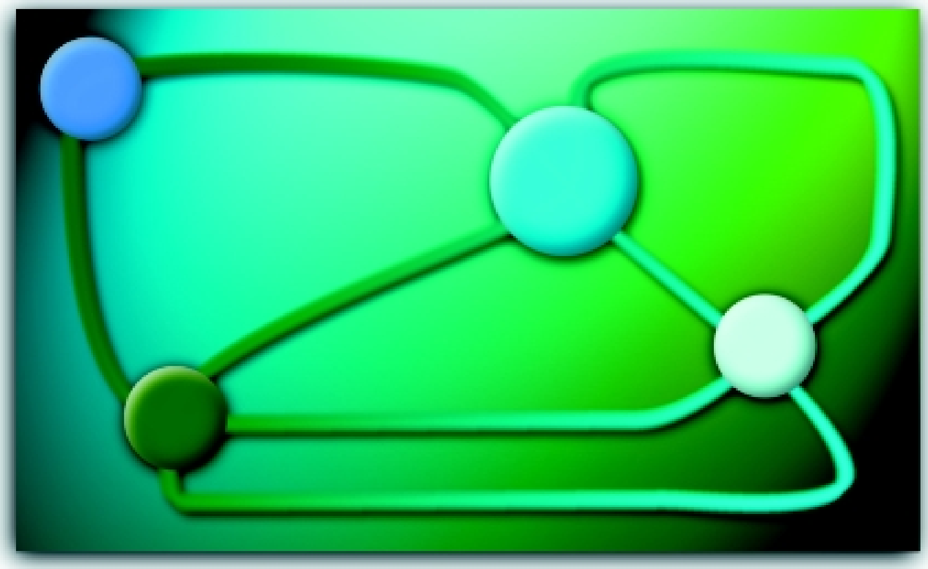
Iris Karvonen

Management of one-of-a-kind manufacturing projects in a distributed environment



TECHNICAL RESEARCH CENTRE OF FINLAND

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VTT Automation

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Abstract

One-of-kind manufacturing, for example deliveries of process plants, fulfil the characteristics of projects and thus also generic project management practices may be applied for them. In the present operation environment the activities are distributed in a network; for each delivery a “virtual enterprise” is created to realise the customer order. The distribution makes the management of the delivery project both important and difficult. In many cases it is necessary to distribute also part of the management by assigning the responsibility of compound elements or tasks to trusted partners.

The distribution increases the importance of information exchange and communication in the project. The project information is important both for the project manager and for efficient project operations. Since the sources and users of the information are distributed tools and channels to exchange and share the information in a user-friendly and acceptable way are needed.

The paper describes a typical manufacturing project and management processes and identifies the information utilised in them. As the role of information is crucial it is discussed, how the project manager and the project team could be supported by information management tools. The work is based on the development of a “project workbench” demonstrator in co-operation with the project managers and team members of a Finnish project contractor.

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1. Introduction

The present report describes part of the research performed in the international IMS (Intelligent Manufacturing Systems) Globeman 21 project completed in 1999. The aim of Globeman 21 was to study methods and tools for Enterprise Integration for Global manufacturing for the 21st Century. The present study deals with one-of-kind manufacturing in a global environment. The application data comes from a Finnish project contractor operating world-wide and the conclusions have been generalized from the specific case and needs of the company.

The goal of this report is to study which methods and tools are needed to manage a delivery project in a distributed environment. The main emphasis is on supporting the project manager in a single project. Management of the project business or multiple projects is not covered. In the first part, Chapters 2–7, the project management process, methods and the effect of distributed operation are discussed. Since the project information is the key item in project management and the research is focused on utilizing information technology, the information groups, structure and sources in the field of project management are described in Chapter 8. Chapter 9 is composed of a high-level specification for a project management support tool from the viewpoint of a project manager and the project team.

2. Manufacturing project

A project is generally defined as a temporary endeavor undertaken to create a unique product or service (PMBOK Guide 1996). One-of-a-kind manufacturing deliveries comply with this definition and thus many of the generic project management practises are suitable also for them.

The modern manufacturing environment and process is quite complex not only due to one-of-a-kind products but also with regard to active parties, location and timing. A typical manufacturing project is described in Figure 1. The delivery process consists of subprocesses or phases which affect each other by producing information, control orders, physical material or equipment. The process is not a simple procedure where phases follow each other. There are two features, which make the difference:

- Concurrency:

  The project phases overlap in time. For example purchasing and manufacturing are started before design is completed. This is necessary for keeping the total leadtime short enough. Quite often the activities of the equipment having the longest delivery time are started first in the project.

- Iteration:

  This mainly concerns design. It is caused by two main factors:

  - To enable concurrency design assumptions must be made to be able to go forward in the project. The design solutions may affect the other design fields, and all the later phases. The correction of the assumptions later, as more information is available, may then cause changes to parts dependent on the corrected item.

  - The design solutions may need modification because of requirements or restrictions observed in later phases, for example during purchasing or planning of transport.

Thus, changes are not an exception; they are part of the project.

The different phases require different knowledge and skills. As the companies are concentrating more and more on their core business and the customers are global, this means the distribution of project activities, often in a global manner. The distribution takes place not only between the project phases, but also inside the phases: all the design or manufacturing is not performed by one party.

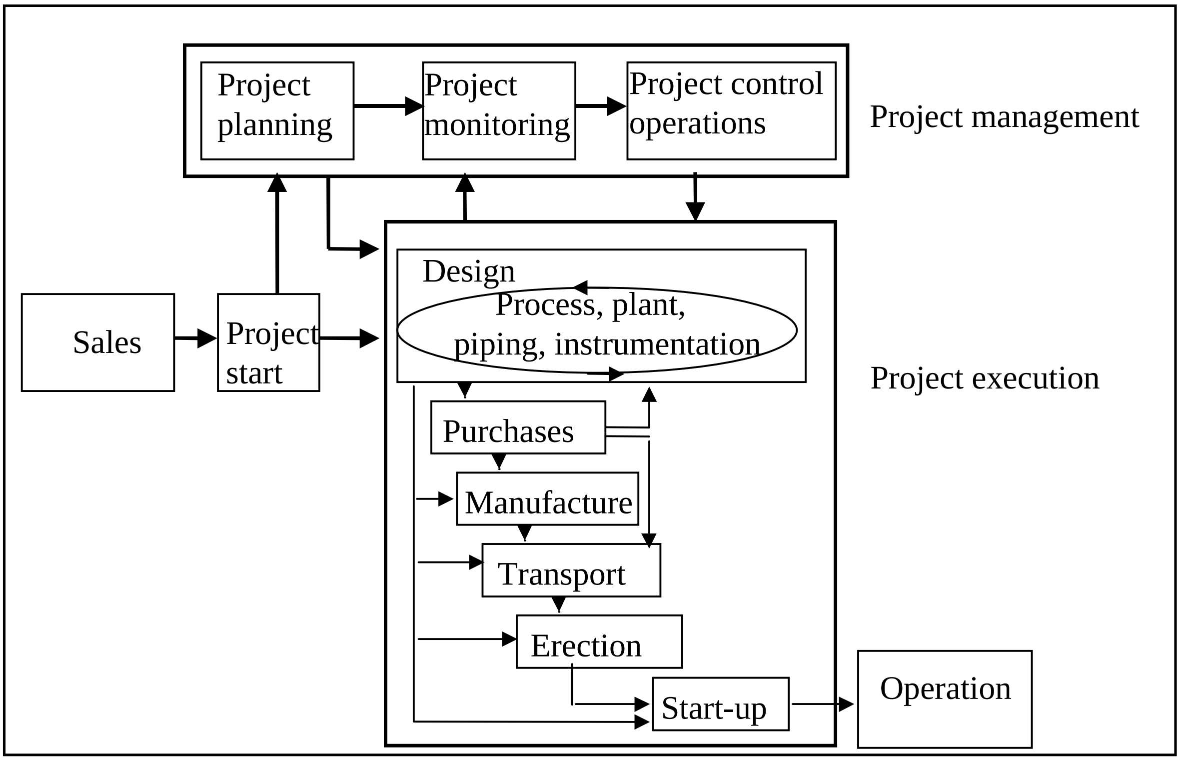

Figure 1. A manufacturing project.

3. Virtual enterprises

Because of the varying demand, different scopes and globally distributed customer deliveries it is most effective to operate in a network, setting up a project consortium from it for each delivery. The partners vary partly from one project to another. This is necessary already because of the distribution of the delivery sites: local subcontractors are always needed. Also the scope of the delivery and the status of resources affect the composition of the project consortium.

The group of companies working together for the customer product is often called a virtual enterprise (VE) because it is composed of individual more or less independent companies. Normally one partner is the co-ordinating partner who signs the contracts with the customer and takes the overall responsibility for the delivery. The Project Manager typically comes from the co-ordinating partner's organisation.

There is a variety of definitions of a virtual enterprise (Vesterager et al. 1999) and probably the definition is still evolving. What is characteristic in many of them is that in addition of the aggregation of core competencies for product delivery also information communication technology (Vesterager et al. 1999), a computer-networked system or information sharing (Chen & Liao 1998) are seen as a prerequisite for a virtual enterprise. In practise, however, this may be more a target than the current state in distributed manufacturing consortiums.

Vesterager et al. (1999) also survey the concepts of network and virtual enterprise in more detail. They base on Generalised Enterprise Reference Architecture (GERAM 1998) when presenting the lifecycles of network, virtual enterprise and product. In addition they introduce descriptive concepts for the network, virtual enterprise and product: situational factors describing the conditions and design parameters of the solution space. These are aimed at supporting the creation and development of networks and virtual enterprises.

However, a classification of the virtual enterprises does not yet give a full picture of the diversity because especially in project deliveries the virtual enterprise is heterogeneous in itself. Inside a virtual enterprise there may be different levels of co-operation between the participants. The permanence of the relationship between the companies affects the nature of the co-operation. A grouping to enterprise networks, partnerships, co-operation and competition (Kuivanen & Hyötyläinen 1997) has been presented. The classification could be applied to project deliveries in the following way:

- Enterprise networks / Partnerships – co-operating in a long-term relationship, in nearly all the projects. The objectives and the strategies of the parties fit together. In many cases the partnership-suppliers have special capabilities for which there are not very many suppliers. The co-operation methods, business processes and information systems may be refined to allow effective co-operation. Co-operation may also exist outside and above the projects including product development. The parties may belong to the same organisation or company or to a different ownership.

- Co-operation: the subcontractors are repeatedly but not constantly taking part in the deliveries. The co-operation outside the projects is not extensive; it is mainly temporary in projects. Some adaptation of operational methods and tools may be performed.

- “Occasional" suppliers, which may be involved only in one project or in several projects. The capabilities required are not very special and they may be easily replaced by another supplier. Most of the subcontractors, which are selected as a result of competitive bidding may be seen to belong to this group. Effective methods to exchange and manage information with this group should be developed, though the IT systems cannot be very closely integrated.

All these types are typically represented in a delivery project. The partners may also take part in other networks.

In many cases the virtual enterprise is partly composed of multi-level VEs which each take the responsibility of a specified component of the product or part of the project (Figure 2). Especially at the partnership and co-operation levels the subcontractors may also be the managers of lower level virtual enterprises. Thus the network/virtual enterprise structure is often partly hierarchical. The different lines between the units in the figure visualise the different co-operation levels.

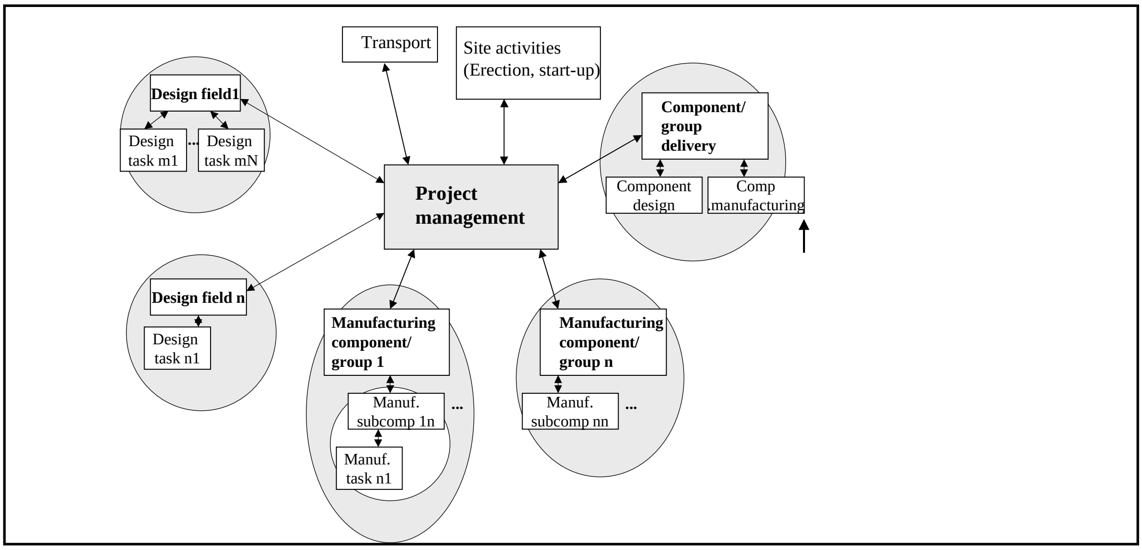

Figure 2. Virtual enterprise hierarchy.

4. Objectives in one-of-kind manufacturing

4.1 Objectives of the project and the project company

A customer expects to have the product within the terms of the contract (time, price and quality). Customer satisfaction is important also for the project contractor: it is a necessary component for its future potential, long term success. Since the one-of-a-kind manufacturing companies live with and from delivery projects, the long term objectives are more important than the short term ones of a single project. If short term results were prioritized the main objective would be to complete each project with a maximum profit fulfilling the minimum customer requirements. Long term objectives affect the objectives of a project (Figure 3).

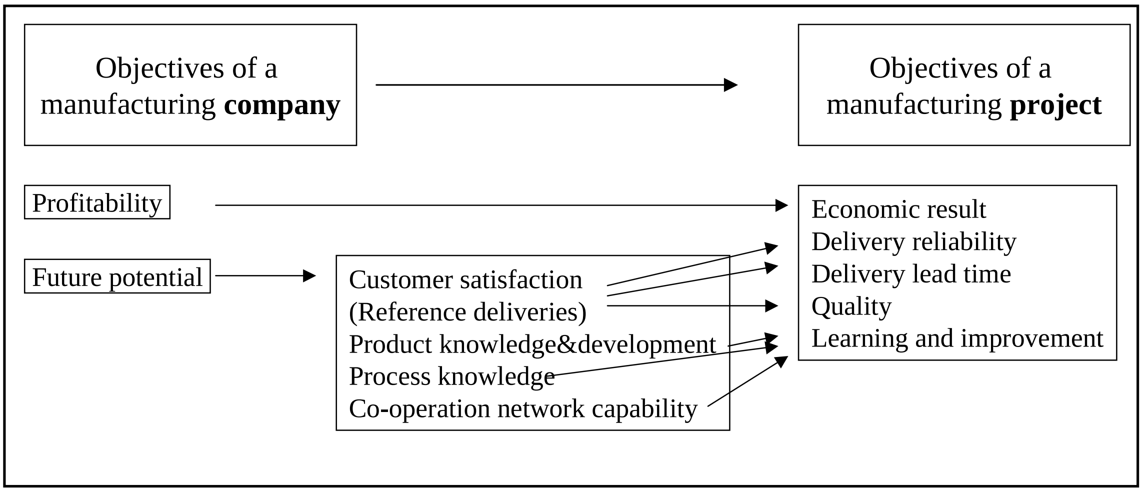

Figure 3. Objectives in manufacturing projects.

The future potential consists of two groups of elements: on the one hand market attractivity for which customer satisfaction, successful delivery references and continuous product development are necessary, and on the other hand, profitability, the maintainability of which requires the tuning of the delivery or manufacturing process and co-operation network.

The main elements in customer satisfaction are the cost, quality of the product and quality of the delivery. The main concern of the last-mentioned is the proposed lead time and delivery reliability. As a manufacturing project is often a hierarchical, partly concurrent set of projects with sequential dependencies the delays of one part affect the others. In addition the quality of delivery includes the quality of the service in customer relationships.

The quality of the product is a broad question depending on the customer preferences. It may include tailoring for customer needs, capacity, controllability, durability, maintainability and reliability of the product as well as requirements or constraints for environmental effects and after-sales services. For a manufacturing project the main task is to take care to fulfil the quality requirements defined in the project contract.

The other side of the future potential, the profitability of the project business, is a broad question affected not only by the performance of projects. For each project this naturally sets the need to keep to the budget. In addition, to be profitable also in the future, continuous development of the product, manufacturing and delivery processes and their management is essential. Though these efforts are needed outside the projects, the project activities should also contribute to them. A recommended method for improvement, learning from experience, must be supported by the project activities. This means that experience data, for example deviation reports, realization of schedules, subcontractor performance etc. is stored during the projects. The collected data helps in the identification of weak points and problem areas and in the definition of improvement measures.

As a conclusion the objective framework of a project and the co-ordinating company is presented in Figure 3. The main objectives, which must be noted and controlled by project management, are: management of costs, keeping due dates and the quality requirements and contributing to development activities by producing data and knowledge and testing new tools and methods in use.

4.2 Objectives of a network

The idea of co-operation networks is to gain more efficiency as each partner is concentrating on its core competence. It is, however, known that the efficiency achieved in one phase of the supply chain can be easily lost in other parts of it. The solution presented is a network view: development of the network elements so that they serve best the whole network and its competitiveness compared to other networks.

In a temporary undertaking, a project, the network view means managing the virtual enterprise so that the supply chain composed of the partners is as efficient and productive as possible. It is quite clear that this objective conforms to the objectives of the customer. However, the application of this objective to the project co-ordinating company and the subcontracting partners is no longer so straightforward. For example, the project co-ordinator may be interested to keep an activity inside the company if there are resources which otherwise would be idle though the same activity could be carried out more effectively outside the company. Also the long perspective goals may overrun the project goals.

The compliance of the objectives of the virtual enterprise and a subcontracting partner is even more vague. Usually the subcontractors operate also with other customers and several networks. Thus, the commitment of the subcontractor is largely dependent on the level of co-operation with the project co-ordinator. If the needs of separate networks conflict it is presumable that the subcontractor prefers the needs of the network giving most benefit for it both in the short and long term. This is one reason why it is advantageous for a project co-ordinating company to develop long term co-operation with the most important subcontractors.

The other way around, the virtual enterprise usually cannot plan the project operations to suit optimally all the partners' schedules. Since the boundary conditions have been fixed with the customer the aim is to keep them. SinceSince the partners are independent companies it is neither in the focus nor possible for the project to create a constant allocation of resources for the partners. The task of managing the manufacturing resources belongs to each partner itself.

5. Project management scope

5.1 Project management objectives and approaches

The task of project management in distributed delivery projects is demanding: it is necessary not only to integrate the results of the virtual enterprise to end up with the required product but the product must be completed achieving customer satisfaction and supporting the objectives of the co-ordinating company. It is not the task of project management to take care of the objectives of the participating subcontractors or partners; as independent companies they have to manage their operations themselves. On the other hand, if the objectives of the partners are highly in line with the project objectives, it contributes to the success of the project.

The objectives considered most important and most difficult affect the focus of the management. In some cases the main problem may be the co-ordination of the integrated technical result whereas the costs and time are seen only as constrained objectives (Anttila et al. 1998). In some other cases most problems are encountered in keeping to the schedule and/or cost limit. If there is a shortage of resources their management within a specified frame of time and costs may become the main issue in a project.

5.2 Project management tasks

Project management is active from the very start to the end of the project; in many cases extending partly also to the preliminary and to the operational phases. A simplified description of project management domain is given in Figure 4. Project management is understood here as a function including the control of the project objectives and their state, co-ordination of the tasks and dealing with the project participants. Project quality control and purchasing are seen here to belong to the project implementation processes (Figure 1) but their planning is considered to be part of the project planning. The definition here is not exclusive; depending on the environment and case project management can be defined to include also the quality assurance and control and procurement and solicitation processes (PMBOK Guide 1996).

As described in Figure 4 project management covers many fields of which:

- control of costs against budget,
- control of project phases and tasks against the required tasks and the schedule and
- fulfilling the customer requirements for the product

are the basic ones. In addition project management is involved in the following functions with other project team members:

- management of resources and/or partners taking part in the project
- customer relationships
- document management
- change management.
- risk management.

The main reference in the management of costs and schedule is the project plan. Typical methods supporting the project management are project reviews and other meetings, project documentation and generic data such as quality handbooks or other project process descriptions. Detailed scheduling of production is not considered a part of project management in distributed projects of independent partners.

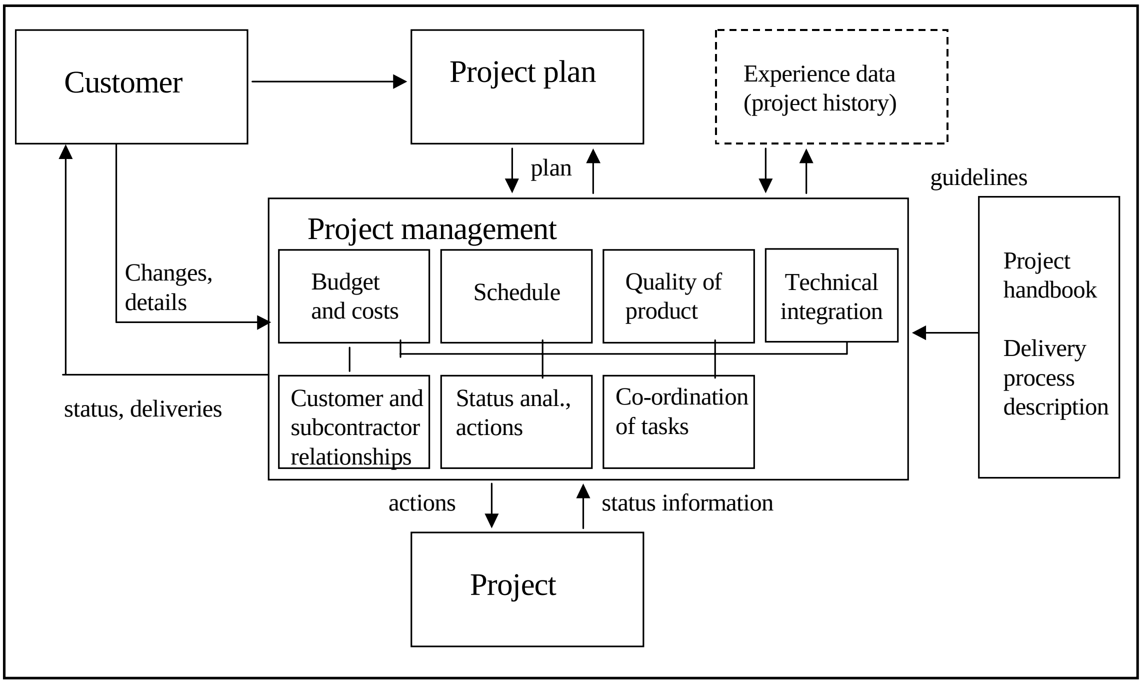

Figure 4. Scope of project management.

In spite of careful project planning, surprises, deviations and problems occur in projects. The problems should be fixed without exceeding the budget or schedule, which in many cases may be difficult. The project management should be able to identify the deviations from the plan to be able to act as early as possible. Thus, a project control which would support the foresight of problems before they actually occur should be preferable. Also what-if-studies, identification of and provision for risks would help in getting through problems. This is discussed further in Chapter 6.

As described earlier the projects are in general carried out in a more or less tight team or group of several companies, a “virtual enterprise”. The distribution enhances the importance of communication in the project consortium. Since the main contractor is responsible also for the subcontracted work the project management is obliged to create the project “enterprise”, guide and control the subcontractors and collect and deliver information through the virtual enterprise.

To decrease the management effort many companies are moving towards distributing also parts of the management by reducing the number of subcontractors and giving them more responsibility. This can be achieved by defining bigger units or modules for the product: the subcontractors do not only deliver a component but a subsystem. The implementation of this trend is dependent on the product configuration. To be effective it requires long-term development of the co-operation, learning to work together and to relying on each other. Also a project information system offering the needed openness and information sharing should be set up as an essential support for this.

6. Project management process

6.1 Process overview

A simple description of the project management process is presented in Figure 5; it is detailed later in Figure 6. The main parts of the process are project planning and monitoring and supervision, which can be viewed as a control loop. In fact more than one loop can be identified since there are many objectives to be controlled, for example the technical content and the activities (Törmä 1997) and, on the other hand, since there are also different sources of information used for the control.

Co-ordination can be understood as the management of dependencies between different entities, in project environment for example the activities (Törmä 1997). Thus, co-ordination is an essential part of project management. Lizotte & Chaib-draa (1997) distinguish two approaches for it: implicit and explicit co-ordination. Implicit co-ordination is based on a priori reasoning, for example rules for the activities and agents. Explicit approach is more dynamic requiring reasoning for the identification of the situation and defining the actions. Usually both types are needed. Using this approach project planning could be seen to belong to the implicit and the monitoring and control to the explicit co-ordination.

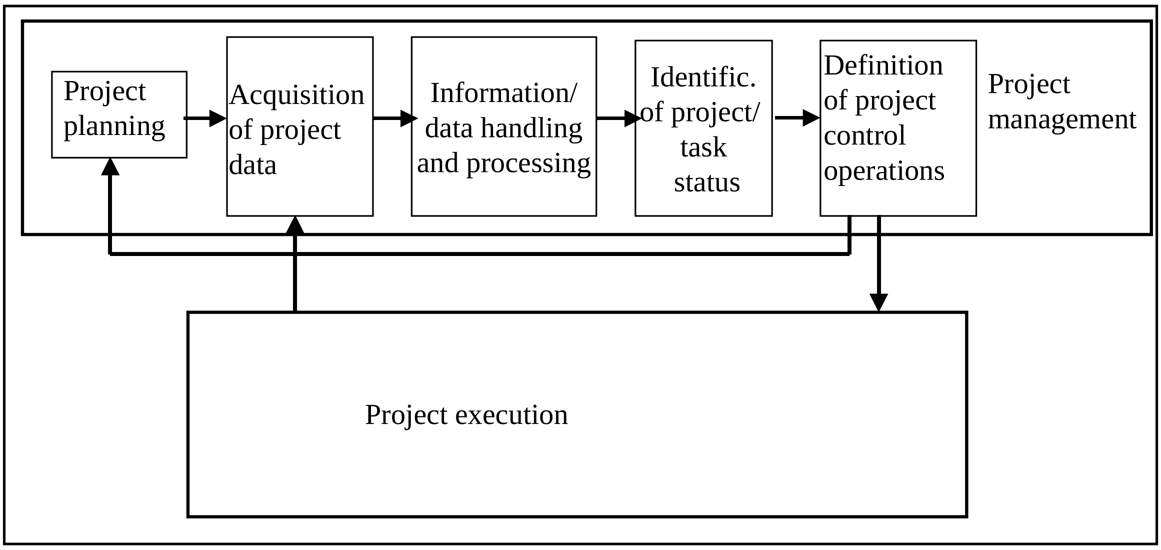

Figure 5. Project management process.

6.2 Project planning

Project planning is the starting point for project management. It breaks down the project and its objectives to sub-elements. The main parts of the project plan include:

- definition of the project tasks (work break-down)
- project schedule: definition of the milestones, the start and end dates of the tasks
- budgeting ; the cost allocation for project subtasks or delivery parts; division into periods
- quality plan: quality control requirements and methods
- project risk analysis; identification of the critical phases and tasks, definition of the special control objects.

The project plan is created in the beginning of the project based on the sales contract. The main due dates, deliveries to the customer cannot be changed without customer agreement. However, more detailed internal dates of the project company, as well as product data "live" during the project. This means that planning is not only a one-off task; detailing, modifications and re-planning of the work and its resources and organisation are needed throughout the project (Törmä 1997). The up-to-date plan is also a useful tool for project control. Management of the costs and the schedule requires that the plan is comparable with the project realisation to follow the project progress and identify the corrections needed.

Hierarchical structures are one method in building and presenting the tasks and schedules especially in large projects. A tree structure is a usual way of presenting the task or product configuration. If the responsibilities of the subtasks are passed to co-operating partners it is also natural to distribute the planning. When the end conditions, the customer delivery due date, are determined the higher level tasks set the limits for the lower levels (subtasks) which may make their own plans in these limits. As the partners providing the tasks are more or less autonomous enterprises the project contractor cannot dictate (and is not interested in dictating) in detail how the subtasks should be planned. If the conditions are not suitable for the lower level they must be re-discussed or another partner taking the task must be found.

If concurrent tasks have dependencies between each other, for example one task uses the intermediate results of another, also horizontal links between the tasks in the plan may be needed.

Quite often the project plan is created according to previous similar projects. Also project templates may exist which describe the typical project structure of the company. Usually in each case, tailoring is needed because the deliveries, suppliers and target locations vary from one project to another.

The tailoring may be performed with the aid of models describing the relationship between project scope (including product configuration) and delivery project (activity) structure. Although it might be possible to build these models very detailed it is necessarily not the best solution: the result, the project plan, must be understandable and not too complex to help in the project management.

When the task structure has been defined it can be used to define the schedule and budget. This requires information about typical durations and costs of the tasks.

In cases where the project configuration is constant but the size or complexity of the product varies the task structure may be nearly the same from one project to another but the task durations and their costs vary. The estimation of the time and cost can in some cases be supported by parametrization: defining parameters which describe the product from the design and manufacturing point of view (for example number of parts, weight, length etc.) and finding out how the task durations and costs depend on these parameters. The same kinds of methods are used also in quite a different field of project planning: in software development projects.

6.3 Project control loops

Project control is here considered as the methods to monitor the project, to identify its status, to evaluate the corrective actions and to respond to the project. The purpose of project control is to direct the project to attain its objectives: keeping the costs in budget limits, deliveries on schedule and quality according to requirements.

Discussing the operations control in a generic, not project oriented, supply chain management environment Fowler (1999) distinguishes two kinds of control loops: feedback and feedforward control. Feedback is sensitive to the monitored output condition as feedforward only monitors the input variables and estimates their effect on the output. Fowler also considers the problems and advantages of different control modes such as their stability / instability, time delays and inaccuracy. He comes to a conclusion that usually a combination of both is needed.

Figure 6 describes the control of a delivery project. It seems evident that here the feedback loop monitoring the achieved results, cumulated costs etc. and defining the actions based on them is more important than the feedforward control. However, there may be some input variables the deviation of which could forecast problems. An example could be the amount of resources bound to a task. Thus, in principle both modes should be considered also in project control to identify the project state.

The project status is concluded mainly from the information received from the project realisation and its comparison to the project plan. In addition the generic and experimental project data are useful data sources for the comparison. Because of the large amount of data, its non-systematic saving, distribution, potential multiplication and ambiguity the reasoning of the status and the operations needed is often not straightforward. The response to the project may be carried out by affecting the project activities or with modifications to the project plan.

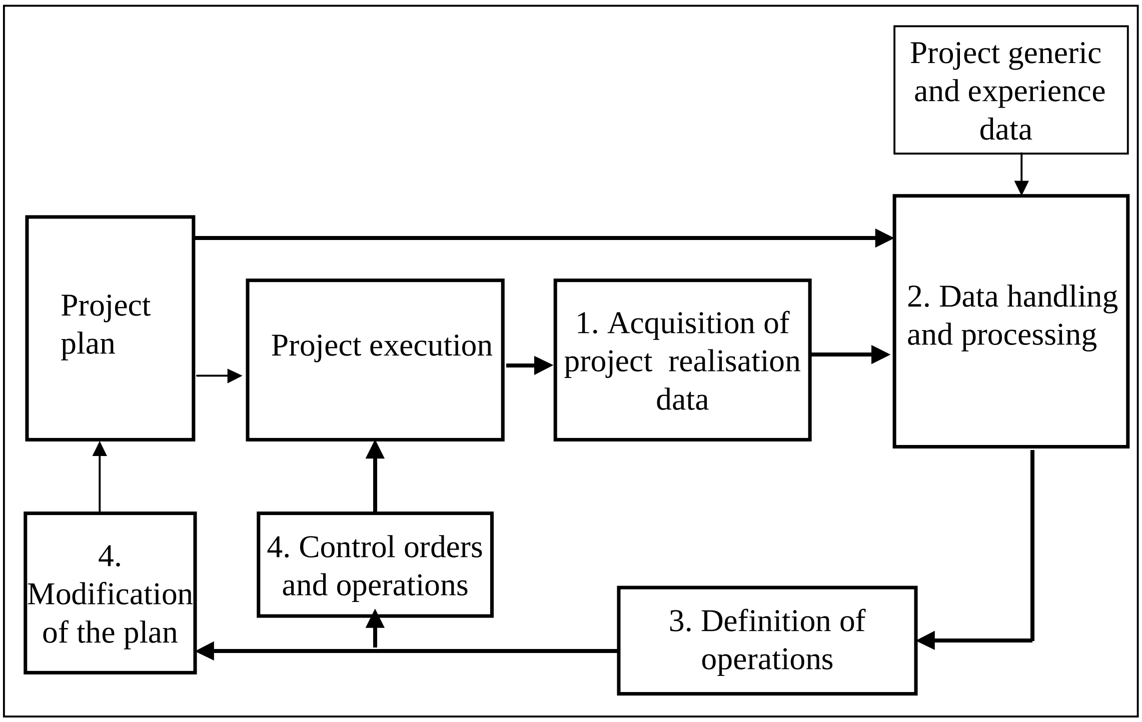

Figure 6. Project control loop.

According to Figure 6 project control has the following steps:

1. Acquisition of information about the project, for example:

- project plan: tasks, schedule and budget
- completed phases and tasks, occurred events
- unaccomplished/ tasks not started
- reserved/ bound resources
- progress of task or phase

- delivered documents and equipment
- cumulated costs
- chosen suppliers
- unsolved questions, missing data
- identified deviations and problems.

This step gives necessary input for the processing of the information on the following steps. However, it is not clear that all the information needed is available and up-to-date. Especially in a distributed environment it is usual that the information is decentralized in many locations and versions. Also all the events (purchases, deliveries etc.) are often not registered so that they are easily controllable. To make the information retrieval easier the following methods can be used (separately and/or together):

- Building up a project information or operational system which offers the access to all the information needed for project management. This does not mean that all the info should be located in the same place or that there should be one integrated system.
- Structuring the tasks in larger entities the responsibilities of which may be delegated to subtasks or subcontractors. This decreases the amount of controllable items on the project level but requires that the partners may work together persistently in several projects to develop workable procedures.
- Developing automated procedures to produce the data about the operations.

2. Data handling and processing: Refinement of the information to identify the project status. The following methods may be used:

- comparison of project plans/ budget and the progress
- comparison with the experience, project history
- definition and evaluation of performance indicators and alarms
- definition of early warnings.

The project plan should be built to support the monitoring; the plan items should be traceable. Definition of critical tasks and project risk identification help in focusing the monitoring. Performance indicators may be used to identify deviations in a large amount of data and to set up alarms and early warnings. Proactive control requires also identifying and predicting potential problems before they occur (chapter 6.4).

An example of the performance measures which can tell more than just the comparison of the schedule and budget separately with the project plan is the “earned value” concept (PMBOK Guide 1996, Välimäki 1995). The earned value indicates the true value of work performed at a given point in time. On an activity level it can be calculated simply by multiplying the cumulative progress with the total budget at completion. The comparison to actual and budgeted costs reveals the status of the activity:

- If earned value is more than both budgeted and actual costs, the project is ahead of schedule and the costs are within the budget.

- If earned value is more than budgeted cost but less than actual costs, the project is ahead of schedule and costs exceed the budget.

- If earned value is less than budgeted cost but more than actual costs, the project is behind schedule and costs are below the budget.

- If earned value is less than both budgeted and actual costs, the project is behind schedule and costs exceed the budget.

3. Definition of the operations needed

Based on the identified status of the project the needed operations are defined. This may include starting up activities, adding resources to delayed tasks, searching missing data, guiding the suppliers etc. Project handbooks may define the actions to be taken into account. If incipient problems are identified it is useful to act before they emerge. If the problems cannot be solved otherwise the project plan may need to be modified.

If there are several alternatives of actions it is useful to compare them with what-if analysis. A method to evaluate the effect of the corrective actions is to use models of dependencies between the project activities. Also the common project management software tools support this kind of analysis. This is discussed further in chapter 7.1.

4. Implementation of the operations focuses either on the modification of the project plan or directly on the project implementation. The updated plan should be made available to the whole project team. As change situations (modification in product design, the project implementation or responsible partners) often cause errors in information transfer it is useful to define the change procedures.

6.4 Reactive and proactive control

The control loop(s) may describe both reactive and proactive control. The data used and the data handling methods for these temporally different modes is partly different. In the reactive mode the control actions are based on problems already occurred, for example due dates passed. Proactive control is aiming to foresee the problems and to act before they arise. That's why the proactive mode may set additional requirements on the planning of the project. Also the focus of monitoring may be different: To enable proactive management " the monitoring should focus on ongoing activities, the management tool thus being deviation reports instead of standard progress reports" (Storholm & Wikström 1995).

In many cases it is difficult to set up pro-active control. Different methods may be needed also within the same project:

- Identification of deviations before their appearance.
- Setting up additional monitoring or checking points in the critical activities.
- Ensuring easy retrieval of the near-by due dates.

If it is possible to evaluate the degree of completion for the project activities easily and reliably enough it may be quite straightforward to identify the deviations. This might be the case for example for an activity of manufacturing N similar pieces. It has also been used for the monitoring of large-scale but rather simple design tasks. In some cases the estimation of remaining work resources compared to the results gained may help to identify the status. However, this is often possible for only few activities in typical one-of-a-kind projects.

Also a kind of proactive control on a higher task level may be built up by setting up a reactive control at a lower level. If a task is divided into subtasks a problem appearing in a subtask is necessarily not yet a problem for the higher task. In case of a delay of a subtask it may still be possible to take impeding actions, so that the problem does not ralise on the higher level.

In some cases feedforward control from the input of a task may expose problems that are not yet visible in the task output. This is true especially for activities, which have a long lead time. It may be too late to act as the deviation has been identified in the output of the task.

In pro-active control the project planning activities are decisive. It does not only include the planning of time and budget but also setting up the plan according to the control needs. This means that special attention is given to problematic phases or activities and setting up triggers which alarm about early symptoms of deviations and problems before they have grown up to delays or excessive costs.

The critical activities, that is, activities with increased risk of failure, can be identified with project risk analysis. There is a broad selection of project risk management methods (PMBOK Guide 1996, Halman & van der Wejden 1997), including quantitative estimates of project measures. However, these methods may become quite laborious. Most often a simple qualitative analysis and focus on responding to the identified risks is adequate for the control function. In the analysis both the effect of deviations of an activity to the whole system and the uncertainty of the activity performance must be taken into account. Project task dependence models are useful for the first part. For the latter both experience and inexperience can be used: the activities with problems in past projects are potential sources for deviations as well as the activities which include unknown, new elements.

In addition of the identification of "weak links" in projects, project experience can also be used to define the warning indications and for solutions to prevent the problems and to overcome them. It is quite common that this knowledge reserve is utilised poorly in organisations.

Apart from alarming for incipient deviations, pro-active control may also be promoted with simple tools, for example by notifying the project management and team about nearing due dates. This is especially advantageous in cases where there are numerous small activities to be controlled. It is also useful in cases of dynamically changing plans.

In general, good preparing for the project execution helps to avoid the problems. Thus also tools like quality and project handbooks, standardisation of the project processes and special attention to information exchange and understanding between the project partners support the proactive operation.

7. Project management structures

7.1 Task/activity structures of projects

The structuring of the project has effect on how easy it is to control. This is especially evident in the planning and change states. If there are complex dependencies between the tasks it is difficult for the project manager to understand the consequences of problems or changes.

Lizotte & Chaib-draa (1997) discuss the co-ordination in concurrent engineering in general (not especially in project environment). They claim that the dependencies between the agents' (players of the project) activities create the need for coordination: "if no dependencies exist then nothing needs to be coordinated". In addition to dependencies between agents' actions (outputs and inputs) they see two other sources for the dependencies between the activities: the common constraints and goals and the situation where no one agent has sufficient competence, resources or information to solve the entire problem. In project environment these requirements are faced already in the planning phase.

There are necessary sequential dependencies between plant component activities: a component cannot be transported before it has been manufactured (if it is not manufactured during the transport!) and installed at the site before it has been manufactured and transported to it. The relation between design, purchasing and manufacturing is not so clear. The critical components having long lead times may be purchased and the manufacturing started before all the design details have been completed. As the components meet at the site in the erection phase they are partly dependent on each other because there are restrictions on the order of the component mountings.

The dependencies between project activities can be illustrated by task models or activity networks. They can be utilised for the planning and control of projects but they could be especially useful in change situations. There are different kinds of dependence models. Precedence diagramming method includes four types of relationships which all are input-output dependencies (PMBOK Guide 1996):

- Finish-to-start: A task cannot be started before another task(s) has been completed (the first ones producing input for the latter). The same may be true also between the subtasks of concurrent tasks.

- Finish-to-finish: the "from" activity must finish before the "to" activity can finish.

- Start-to-start: the “from” activity must start before the “to” activity can start.
- Start-to-finish: the “from” activity must start before the “to” activity can finish.

The first alternative is the one used most often (Figure 7). Some dependence methods always assume the finish-to-start relationship.

Though the dependencies described above may be very complex to handle in practise they are not always adequate. In addition there may be conditional and concurrence dependencies:

- Conditional branching: depending on the circumstances the project may follow different routes.
- Iteration: it may be required to iterate some activities or return back in case of changes.
- A task cannot be performed at the same time with another task (dependence on the same resources).
- A task must be performed at the same time with another task. In case the performing partner is the same for both tasks they could be combined into one task.

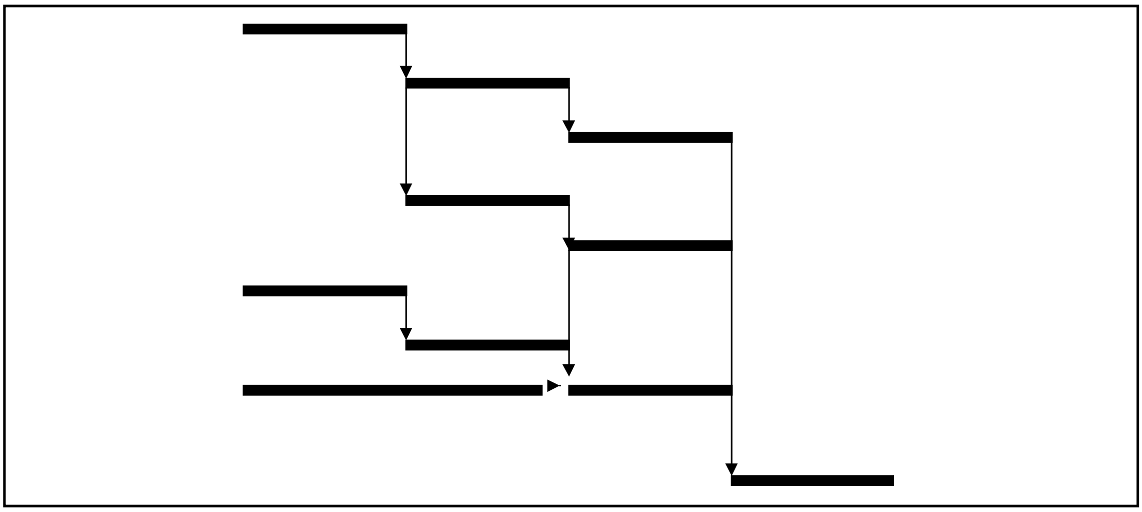

Figure 7. Example of output-input dependence.

The dependencies can be presented with different kinds of project diagrams. The series of activities which determines the earliest completion of the project is called a critical path (PMBOK Guide 1996). The corresponding network analysis technique is called critical path method.

The available project management software packages support some of the relationships, the main mode being input-output dependencies. In case of a change in the timing of a task (for example a delay) its effect on the task chain may be viewed. The function may be used for what-if studies: alternative actions may be compared.

Barbuceanu et al. (1997, 1998) discuss the coordination of multiple agents; one application being the inter-enterprise supply chains. Their aim is to develop a coordination language to build artificial multi-agent systems: In addition of what-if studies they aim to support or even automate also the decision about the selection of the alternative actions in contradictory situations. They represent the dependencies between the agents' activities as obligations, permissions and interdictions among the roles the agents play in an organisation. In their model the co-ordinator may impose constraints associated with a cost in case of a violation on the agent. The cost is used in conflicting situations to select the alternative with smallest penalties.

The tools supporting the dependence modelling of project activities do not make the management of dependent tasks easy in one-of-kind delivery projects. The project manager cannot rely on automated inference; he / she must be able to understand the state of the project and changes caused. Thus, using the dependence modelling does not as such solve any problems; the main question is how the model should be built. If the dependence structures are complex the modification of the project plan may cause quite unexpected consequences that are difficult to follow. To be controllable it is recommended that only simple and quite clear dependencies are used. One option is to use only component-based dependencies.

Another reason, which decreases the use of complex dependence diagrams, is that in practise new ways, sequential orders or additional partners for carrying out a task may be implemented as changes are made to the plan. It is very difficult or even impossible to build a project model which would present all the potential alternative routes or methods.

Thus the project structure has an effect on how easy it is to control. In the same way as in process engineering it is not a good solution to create a system operable only under a demanding and complex control. Instead the system, in this case a project, should be inherently operable and reliable. One way to attain the goal is to use as simple project structures as possible. Complex internal dependencies should be avoided though it is, of course, not possible to completely eliminate them. To enable concurrency, for example, dependencies between the tasks are generated.

One way to run into trouble is to have strong resource-based dependencies between the tasks which otherwise were independent. If for example two concurrently and/or sequentially planned, otherwise independent tasks are performed by the same limited resources, the difficulties of one task very easily propagate also to the other task if they are to be performed quite near each other in the schedule. If the first task is delayed it is not possible to start the other task in time or put enough resources into it. This again may cause unexpected problems in other parts of the project.

7.2 Control of a distributed project

Control of a networked delivery project is distributed in two respects:

- The activities and partners to be controlled are distributed.
- The control of the project itself is partly distributed: the subtasks have their own management function. However, to achieve the project objectives also integrative project management is needed (for example hierarchic integration).

Figure 8 describes the distribution of a delivery project from the activity point of view. As the project is started the product (plant) is a design collection of lines and processes or other subparts. As the design progresses it is divided into several design fields or areas (factory design, process design…) which may be performed by different partners. The design areas may have interdependencies, which must be taken into account. To allow concurrency, design assumptions must be made in the beginning.

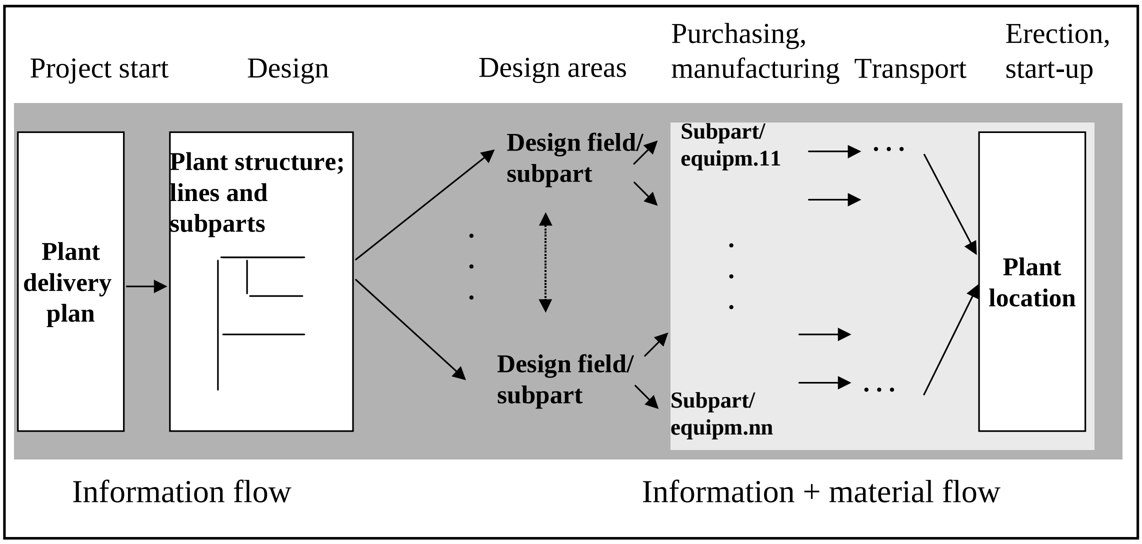

Figure 8. Plant decomposition.

The different design areas produce details about the equipment and components for purchasing and manufacturing. Thus the plant is divided into multiple components and component groups which require their own activities in the purchasing, manufacturing and transport phases until they all meet again on the plant site. Because all the components are not installed at the same time all these components or groups have their own due dates for purchasing, manufacturing and transporting to the site. As stated in the previous chapter the activities concerning the same component have unavoidable dependencies with each other. If the different phases of a component have different responsible partners, dependencies are created between the distributed participants. The dependencies must be taken into account in planning and monitoring the project.

Components having the same manufacturer and near-by due dates may be combined in the same order and components having near-by due dates and transport routes may be combined together in the same shipment. If the group remains together for the rest of the project it may be handled in each activity as one compounded component and activity. For the groups, which spread out later in the project, it should be possible to follow the status of each component to identify deviations. At present, it is in many cases a difficult or even an impossible task. The only practical way to have the data is to automate the collection. In large distributed projects manual registering is not realistic. One way is to perform as many operations as possible in the purchasing, manufacturing and shipment / transport tasks within an information system the data of which is available for the project management. Also bar coding for the arrival and completion reports can be used.

The distribution or placing out the activities to subcontractors or partners can be organised in different ways. First, there are different levels of co-operation as discussed in Chapter 3. The closer the co-operation, the wider responsibility can be given to the outside partners who again may build up the lower level “virtual enterprises” using their own networks. If the co-operation is not sound enough the project management cannot delegate as demanding activities as it would otherwise, and more control is needed.

Second, the “virtual enterprises” can be formed or the tasks allocated in basically two ways:

- defining the responsibilities according to the activities, or

- defining them in relation to the components of the product (or creating an aggregated activity composed of the component activities).

The piping of a process plant could be used as an example: In the first case the piping design could belong to the overall design task and piping production to another partner. In the latter case the whole piping delivery containing both design, manufacturing, transport and installation could be allocated to a "piping partner". In many cases both methods are used parallelly in the same project for different tasks/ components.

The distribution of project activities relates to the product structure, its configuration and modularisation. They define the constructional parts of the system. Also the specification of the core competence of the project contractor has an effect on what should be kept inside the company and what outsourced.

There are many items which affect the best available distribution method, and it is not possible to switch instantaneously from one to another. To keep the project controllable at least two points should be kept in view:

- The interfaces between the distributed tasks should be clear.

- The distribution should not create unnecessary interdependencies between the activities.

Allocating the subtasks to "sub-virtual enterprises" means also the distribution of the project control: as the subcontracting partner takes the responsibility of the subtask it also assumes control for it. If the project task structure and plan are hierarchically structured, the project control may likewise be hierarchically distributed on different subtask levels. Thus each level manages its activities and the project manager need not follow the sub-subtasks in detail. In a network this requires that the partners are used to working together and they know the rules of co-operation. The project manager must be able to rely on being informed about deviations and problems in the subtask as soon as they appear. However, as an exception, it might be in the interest of the project manager to follow the most critical sub-subtask level activities more closely.

In addition there may be a need for co-ordination between horizontal tasks. This can be effected in basically two ways: either creating direct horizontal links between the tasks or managing the links at the next higher level. In the first case it is often also necessary to inform the higher level about what is happening horizontally below. The suitable management structure is dependent on the type of the need for the horizontal co-operation and its effect on the other parts of the project, and also on the co-operation experience of the partners. The less co-operation experience, the stronger management is needed.

8. Project information

8.1 Project information contents

As could be seen in the previous chapters, information is the key item in the project management. The information is needed to understand the status of the project and to decide about the actions for delivering the product on time and within the budget. It is also essential to build the product according to design specifications and customer requirements.

The project information groups are presented in Figure 9. According to the degree of generality the data can be divided into generic and (project) specific data. Both data types include three main groups: product (what should be delivered), project (how and when the work should be carried out) and organisational data (who is doing what).

8.2 Generic project information

The generic data is common to all the projects of a project contractor though not all of it can be used in each project. The generic data includes:

- Generic product data: configuration, reference processes, product models, component database etc.
- Generic project configuration models: reference work breakdown structures, typical durations of tasks, schedule templates etc. can be used for project planning.
- Generic quality assurance and inspection methods.
- Project handbook and project process descriptions provide the general company-specific framework for the projects.
- Standards, country-specific or wider.
- Organisational data about subcontractors and partners, their products and capabilities.

The collection of the data from different executed projects composing the project history set is also a valuable knowledge storage. In each case the ones with the closest resemblance to the present project can be selected. The utilisation of this knowledge is, however, not straightforward. In case of a similar product and delivery extent a different target location or the participants included may make the difference.

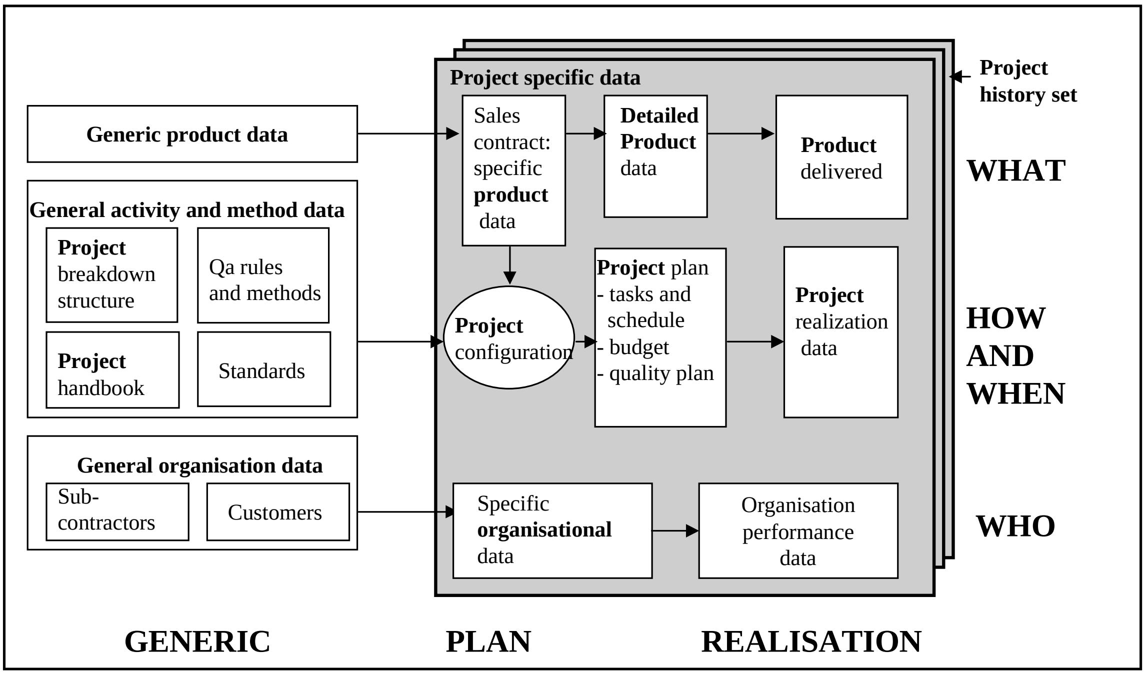

Figure 9. Project information.

8.3 Project-specific information

The project specific data includes:

Product data (what is the result of the project?):

- Product configuration
- Delivery content
- Process diagram, descriptions and parameters
- Equipment included
- Equipment characteristics and details
- Applied standards

Project data (how and when is it achieved):

- Project configuration: phases and tasks
- Schedule; planned due dates and deliveries

- Budget and costs
- Quality inspection rules and methods
- Accomplished deliveries and occurred events
- Given purchase orders
- Task or equipment status information

Organisation/ Partners (Who makes it?):

- Contact data
- Roles and responsibilities
- Available suppliers
- Supplier experience

The generic data can be used as the basis when creating project specific data.

8.4 Information stability and quality

Most of the project-specific data is not stable in a project. An exception may be the project contract defining the terms of the delivery to the customer. The project plan establishes the base for the project data in the initial stage. During the project the plan is updated, the product is designed in detail and data about the project events, for example orders, deliveries and reviews, is created. The sources of the new data are distributed. It is created by the customer, by the company team and different subcontractors.

The different versions of the project data following changes and detailing the design need to be carefully monitored in order to be aware of the up-to-date information. The quality of the information varies also in other respects: in addition to becoming obsolete the data may be only guesses or assumptions needed for concurrent progress of the project activities. The information may be inaccurate, incomplete or uncertain and if the type of the information is not known it is difficult to use it.

8.5 Users of project information

The different roles in a delivery project also affect the use of the information. The project manager is responsible for the control of the project costs and schedule as well as the co-ordination of tasks, partners and customer relationships. On the other hand, the different tasks may have their own management roles, for example the main designer is responsible for adjusting the different design domains. Thus there may be the similar needs for the management at different project levels.

The information exchange in the project is multi-directional (Figure 10). Also the management role is interactive: both utilising the information and creating new data and control orders. In the beginning a project plan is created, later it may be updated. As the project moves along, changes are carried out and the project progress is monitored. The project manager (or task managers) may also set up some status flags but the status data used should mainly come from the operations. The project manager must ensure that the partners have the information they need for their task. In case of changes in the project scope or product design, task schedule or the order of tasks it its important to supply correct and sufficient information.

The players in the project team: in design, purchasing, manufacturing, transport, erection and start-up phases, all need some basic, common information about the project. In addition each of these groups has its special needs for data. Though certain openness is needed the partners must not be overwhelmed with excessive information. Moreover, some of the data is confidential and not open to all the partners.

In addition to utilising data, project partners create a lot of product information needed in the subsequent design, manufacturing, shipment or erection phases. The activities are the main source for the project status information used by the project manager to monitor the progress of the process. The creation of the status information or the underlying data should be automated as far as possible. For example, the status information could be created and updated at the same time as a document or an action is completed.

The information can be disclosed also to distributed partners. The sharing of information between different companies usually requires detailed consideration about the publicity of the data. It is necessary to define which part of the data is open and which not. The user rights, viewing or editing, must be defined for both in-company and outside users. Different user roles may be used for these definitions.

Though the product requirements have been specified in the contract, more detailed information about the product will usually be required from the customer during the design phase. The same concerns the project data; especially the status of the tasks belonging to the customer or taken by other consortiums. On the other hand, the customer is provided with product and status information on the project. The project information workbench could thus support also the customer and work as a means to create and maintain trust between the project contractor and the customer.

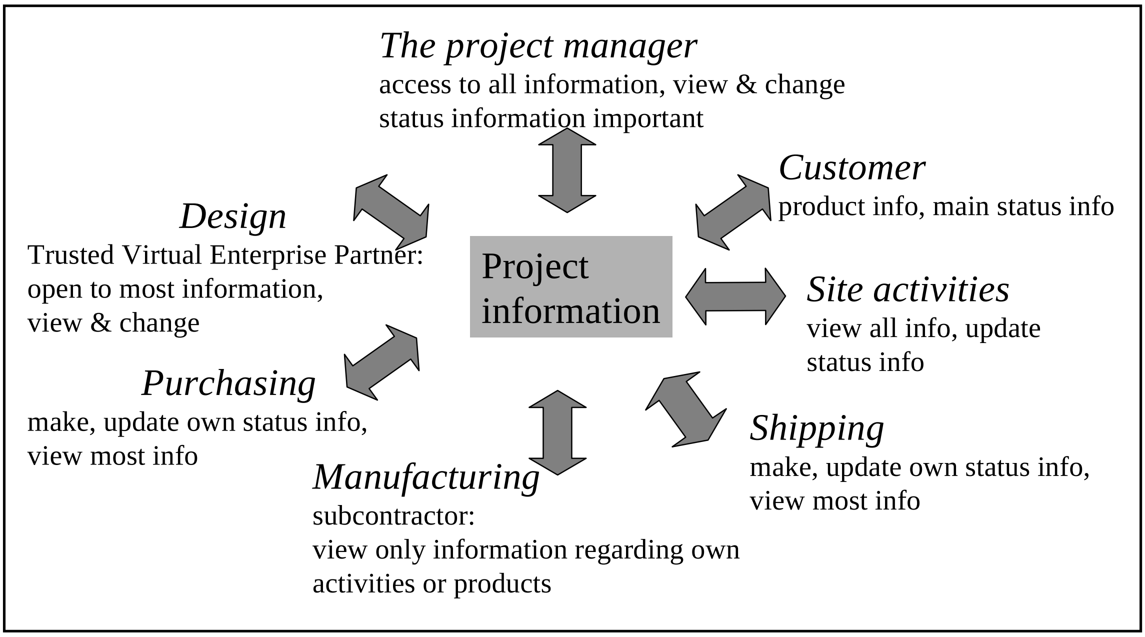

Figure 10. User roles of project information.

9. Project workbench - Supporting the information management in distributed one-of-a-kind manufacturing

9.1 Objectives of support

The large variety, multiple users and the distribution of the project information complicates its management. Most often the project information is not easily available and understandable. It may be distributed in several locations. The same information may be saved in many places in different versions, the updating of which is imperfect. Aggregation of information coming from different sources may be impossible. Part of the information is only in the minds of the participants which makes its utilisation restricted.

To monitor the project status information, details of tasks started and completed or their progress were needed. In a distributed environment it is, however, quite difficult to collect the data. For this, automated procedures which produce the data were the most effective and reliable. It is difficult to find acceptance and retrieve reliable results if additional manual operations are needed to provide the status information.

Information management support may decrease the time used for searching fragments of data and thus make the operations more efficient. At the same time the support may help to avoid errors caused by misunderstandings or out-of-date data. Thus user-friendly information management may contribute to the reduction of costs, shortening the lead time and ensuring the quality.

Moreover, project management support decreases the uncertainty of the project by helping in the identification of the project status. It thus reinforces the reliability of delivering the product on time and within the budget.

Similarly to different users of the project information there are different user groups which would benefit of the tools for the information exchange and management. In addition to the project manager the whole project team should be supported in information handling, communication and collaboration. The following requirements are common to the whole distributed team:

- The up-to-date information and documentation should be easily available. This does not mean that all the information should be saved in one location. The aim is that the user does not need to know where the information is located but can at all times rely on that the version offered is the latest. Likewise, the large amounts of different kinds of information should be structured so that each piece of data could be traced down easily. One way is to use the hierarchical project (activity and product) structures.

- The support system should offer easy routes to view the data linked to each other: for example the product and the corresponding activities could be interlinked.

- The communication and collaboration among the distributed project team should be supported. Since there are different partners in the virtual enterprise different levels of information exchange are also needed.

The project (and subtask) managers have additional needs for the co-ordination of the project:

- Support in project planning should be given to create the work breakdown, budget, schedule and other plan material. Special attention should be given to make the project plan a tool in the monitoring and control of the project.

- The project management should be helped to understand the status: the entire project status should be shown and support given in identifying deviations and possible problems, showing ways to details and causes behind problems and assistance in planning the actions. In many cases the scope of this information is too large to be viewed thoroughly. Thus selection, refinement and interpretation of the information is required. To identify deviations only one data class is not enough; comparison and aggregation of different fragments of data is required. For example, following the cumulation of costs with time alone may lead to the false conclusion that the budget is followed also in cases where the project is behind the schedule, and thus, in fact, costs may exceed the budget for the completed tasks.

9.2 Levels of support

The information system support can be applied on different levels depending on the degree of automation or intelligence seen useful:

1. Information made available

On the lowest level the information system provides easily available up-to-date information and documentation to the project manager and other team members as such, without any refinement. The presentation of the information should give the user an illustrative overall view and help in finding routes to the interesting details, for example by presenting links between different fragments of data. This function alone is extensive and very beneficial in practise.

As the data, especially the product design, evolves during the project from assumptions to details set up it is essential to display the design versions and/ or data quality type (initial assumption/ fixed value). It may also be useful to display the date and source of the data, for example the designer who created the version.

As discussed in Chapter 8, the different users of the project information have different needs and rights to view it. The project manager must have access to all the project information but naturally all the data of the external companies is not available to him/her. The project team members, for example purchasing or shipping, need a specific part of the information. Among the external subcontractors there may likewise be different user rights.

2. Information refinement

On the second level of support the information is not only viewed as such but refined to identify the status and to foresee potential problems and deviations. The tool should offer possibilities to analyse the data and to compare the different fragments of data with each other. The function is especially important for the project managers.

3. Decision support, qualitative knowledge

The system could support the project manager or subtask managers with active data creation:

- project planning support
- decision-making about actions needed and comparison of different alternatives.

It is quite clear that the decision making cannot be fully automated so that the system could make the decisions. The support system may only give propositions, the user may agree or disagree with them. The most important thing is to help the user to understand the situation and the potential alternatives.

4. Automated actions or procedures

The fourth level of support is the automatic implementation of the actions. The project management tool could support part of the operations especially dealing with:

- Information delivery and collaboration between partners
- Procedures and support for implementing changes
- Generation of status information from the operations. This is needed to identify the project and task statuses.

The levels are described in Figure 11. Going from level 1 to level 4 the intelligence or automation of the support increases. On the other hand, the application scope decreases in the same direction. Thus, though the support intelligence is the lowest on level 1 this level has the most significance because it concerns all the information and all the users.

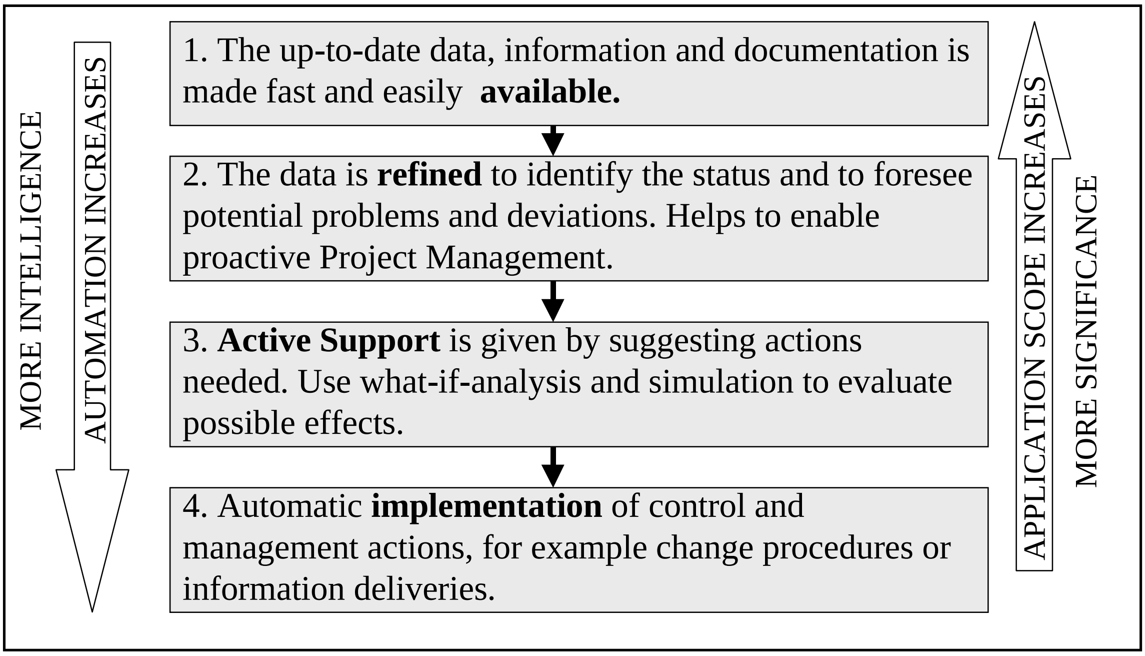

Figure 11. Levels of information management support.

9.3 Functional groups of project workbench

9.3.1 Information repository and information access

The group corresponds to the first level of support in Figure 11: making the project information available in a transparent way.

Supporting the information availability may mean that the metadata, the information about the project information, is presented to the user as a project homepage with links to project data, or a project workbench is created by collecting the links to project tools and information together. The data and tools as such may be distributed in different systems and even geographical sites and the user does not need to know where each fragment of data is located. One solution used is to implement web-interfaces to existing project files and databases which make the distributed utilisation of distributed information easy (Basak 1999).

The presentation of information requires the modelling of its contents. It is necessary to create metadata, the description of the information, to support its utilisation. The different users of the information and the processes where the information is used must be taken into account in the data models.

Classification and grouping help the user to find the needed data item. For example product, activity and organisation routes may be used. Since a part of the data is valid for the whole project and a part for a specified activity or component, hierarchic structures of products and tasks can be used to guide the user. To avoid browsing the hierarchies up and down links between related data items, for example the component and the related activities could be set up. Visualisation of the information scope and structure also helps the user.

Because of different access permissions and user rights the system could offer the different users different views to the information. According to user role there could be direct links to the most important data and the data not allowed could be hidden.

The project information repository may also include wholly unstructured information like messages and different kinds of notes, which do not necessarily belong to any official data, but may be important for the users. An example is the +/- -lists in which the project manager collects the deviations from the project contract effecting the costs.

The information sources which are not project-specific like quality handbooks, process descriptions and standards etc. as described in chapter 7.3 should be included in the information model. They are the easiest part to initiate the implementation of the support as this information is more stable than the project specific information.

The accumulation of the project info also helps to make available the experience of the previous projects, the project history. The large information masses may require search functions.

In addition to the data inside the project team or the company the project workbench should have links to useful outside data. Bookmarks for useful internet locations could be predefined for the data available in the internet. This may include links to different standards, weather and traffic conditions, maps, transport services etc. The supply of internet and wireless services, especially restricted, chargeable services is all the time increasing.

9.3.2 Document handling

A typical outcome of the project functions is information presented as a document. The documents are used in the information exchange between the project team members, customer and subcontractors. Increasingly the document contents are also saved in a database so that the document is only a partial or full print-out of the database. The database solution helps the information management of the project if the data access is not denied. It decreases the amount of manual operations needed and ensures that up-to-date information is always used.

The database solution does not eliminate the need to manage the versions of the documents or underlying data. If a version must be stored typically both the database state and the output document are saved. The versioning is the task of the tool by which the data is created and modified. Thus, if project workbench has a (read-only) access to the design databases which are edited by the design tool, it is the responsibility of the design tools to manage the versions. On the other hand, in case the project tool offers services for editing the data or documents of for example purchase orders it must also take care of the versions.

Beside the database print-outs also text-based documents are created and used. The project workbench may offer the following support:

- templates for creating the documents, for example for meeting minutes and progress and quality review sheets.
- methods of saving the documents in predefined structures
- easy routes to access the documents.

9.3.3 Project management

9.3.3.1 Project start-up and project planning

The project start-up includes the creation of the project and the definition of its basic information, setup of the needed structures and the first “project net”, the information network. The project management workbench may offer functions for the input of this data. For the structures also templates may be used.

Customer and project organisation data (responsibility, contact information), mailing lists etc. should be set up as soon as possible. As the project team, project manager and those responsible for the main tasks have been defined, the first user roles or the user rights for the project information should be set up. The task continues throughout the project as new members enter the project or leave it. Thus, easy and secure methods for the access rights must be developed.

The project plan objectives and contents are discussed in Chapter 6.2. It can be seen as a collection of information at the project start including data on :

- contract with the customer
- product data at the time of contract
- responsibilities already defined
- project tasks (work break-down)
- project schedule (milestones, the start and end dates)
- budget; cost allocation for subtasks and subparts
- quality plan
- project risk analysis.

Most of this data is not available at the project start but it must be created. For this different data sources can be used:

- The data available from the sales phase and the project contract. This includes the preliminary product data and the main milestones of the project (customer delivery due dates) and other customer requirements. It must be ensured that the latest data, updated according to the sales contract, is forwarded to the project.

- The project history or experience from previous projects can be utilised to construct templates of typical project structures and schedules. Thus the work break-down does not need to start each time from scratch but templates can be modified to define the tasks and schedule.

- Models binding together the project and the product configuration can also be developed and used to tailor the generic project template according to the specific customer project (Figure 12). The model could describe the dependencies between the delivery contents (product configuration and other services) and the project break-down.

The project manager is interested to see the project plan at the level he /she is managing the tasks. The managers of different subtasks may again build up a more detailed plan in the limits given by the overall schedule or budget. Thus the planning may be distributed. It is also in the interest of the project manager to follow the most critical tasks at a more detailed level to be able to foresee problems and deviations. Thus the project plan, especially the tasks and schedule, should be available at selected levels for different partners in the project team, for example:

- The schedule of the main tasks visible for all the team members.

- The detailed schedule of each task available for the partners operating in it or dependent on it.

- The project manager has access to all the levels if needed, but operates mainly on the upper levels.

- The budget is normally seen to include more confidential information but there is also a trend to “open books” in more static networks. Thus it depends on the type of the network relationships if it is available for the partners or not.

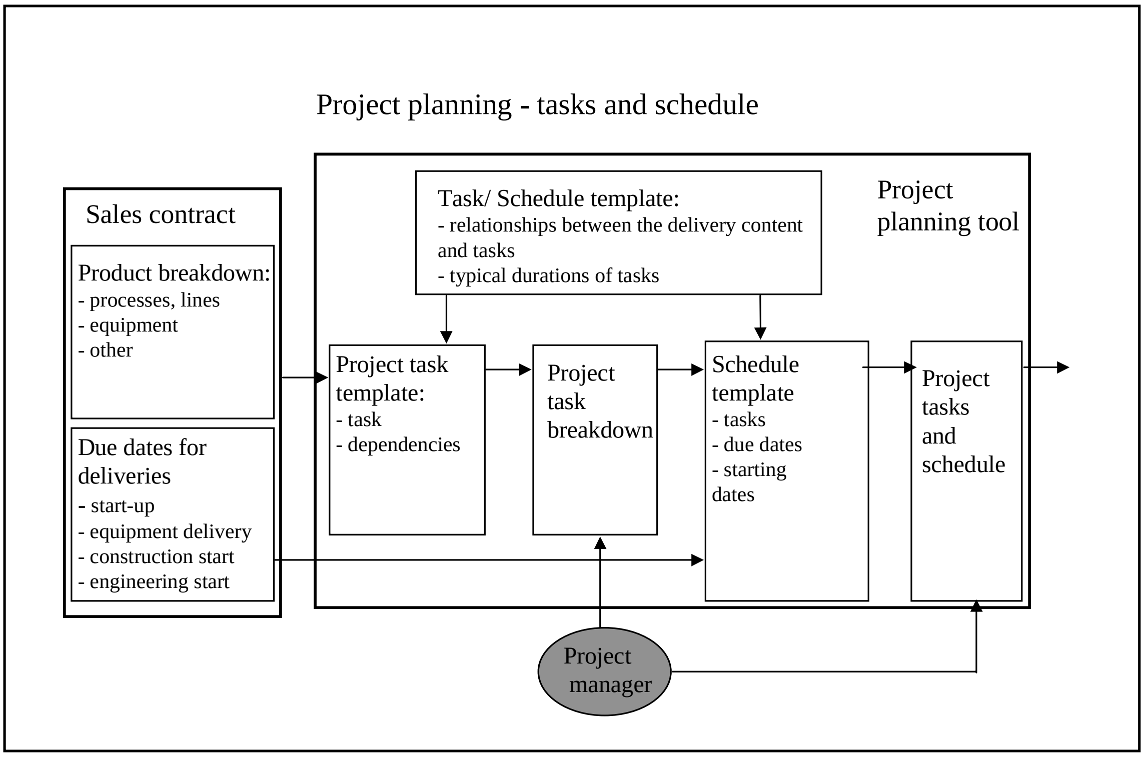

Figure 12. Utilising templates or models for tasks and schedule.

9.3.3.2 Project management

Project management is mainly information management and utilisation to activate, guide and control the project tasks. The support of level 1 of Figure 11 is thus the most significant also for the project manager. On the other hand, the project management has most interest and use for the level 2 support: the refinement of the data to follow the project and to identify the status. Decision support on level 3 and selected functions of level 4 may likewise be valuable for the project managers.

The information groups in project monitoring and management are mainly the same as in the project planning phase. In addition to creation of information now also detailing, modification and interpretation is needed. The plans may need updating and, in addition, data about their realisation begin to accumulate. The main items of interest for the project manager are:

- costs and budget
- tasks, schedule and status
- documents

- product data, including changes
- resources and partners
- quality requirements and results.

To be able to react and proact the project managers need to identify the deviations and problems in the project (level 2). A typical way to do this is to compare the situation with the project plan. A simple but useful method is to collect all the due dates in the near future (for example in the next two weeks) and to present them to the project manager. This is especially useful in cases when there are numerous items to be controlled. Respectively, the search could be made to the past; for example to collect all the documents completed in a time period. Performance indicators evaluated from project realisation data may also be useful. Alarms and warnings may be defined to point out overflowing costs or deliveries that are already late or becoming late. This may require an understanding of the effects of potential deviations to the plan.

To enable the comparison the project plan should be built to support the project monitoring. The data of previous projects can be used for the comparison. To keep the analysis as simple as possible it is useful to identify the critical tasks and to put more focus and details on them.

Alternative actions could be evaluated for example with a what-if-analysis showing their effect to the project. Activity network descriptions, which are not too complex, may be helpful here. One possibility is to use component-based dependencies.

If sufficient knowledge is collected and modelled even an expert system giving advice could be constructed. However, it is not clear how beneficial such a system could be.

9.3.4 Support to project assistant operations

Project management system may also include functions, which support the performance of the project routine operations, like purchasing, transport arrangements and erection management. Alternatively a separate system supporting the routines can be linked to the system. Potential functions include:

- Purchasing: planning, retrieval of the components and material to be purchased, selection of subcontractors, inquiries, ordering, order confirmation, updates of the subcontractor experience data.

- Shipping: planning, transport management, reception of dispatch notes, packaging planning, package bills.

- Erection: planning, reception of dispatch shipments, review notes, approval checks.

The support for operations is useful also from the project management point of view for the following reasons:

- Standardization and support for the project procedures helps in making the delivery process more effective and easier to manage.

- The support of the project tool for the operations, especially the improved information retrieval, decreases errors caused by using out-of-date data.

- The incorporation of the operations to the workbench makes it possible to automatically retrieve data about the state of the operations (for example about equipment purchased or transported). For example the following functions may be used:

- Saving a document may create the data about its versions and completion status.

- Making an order is saved as an event with time stamps in the database.

- Delivering and/or receiving a component is registered for example with bar codes.

Many of the project routines, like purchasing and expeding, require actions in several lots or stages of the project. Moreover, it is quite usual that the same person takes care of several projects at the same time. He/she is then switching from the tasks of one project to another all the time, which makes it more difficult to bring back the current state of each project. The project workbench could help here by presenting the essential information about the project from the perspective of each function: the necessary product data, the status of the functions, the next phases and their due dates or tasks waiting for input or feedback from other parties. Thus, in addition of the overall schedule also a schedule tailored for each function should be available. If the whole project schedule is saved in a database this may be achieved by taking different views on it.

The support to project operations may include all the levels from 1 to 4: the access to the information is needed for all tasks. Some of them also require the refinement of the information and other more intelligent features.

9.3.5 Information exchange and integration with subcontractors/partners

If the project data is shared in the project team as described in 9.3.1 the main route of information exchange may go directly by accessing the project information repository, for example project databases. It may be practical to deliver some information as electronic mail. However, the utilisation of electronic mail easily leads to disordered management of the messages and the attached information. From the project management view the electronic messaging would require very disciplined working and archiving methods and the follow-up of the message chains.

In the project team usual collaboration tools like bulletin boards, group calendars etc. may also be useful. For essential information, for example about changes, bulletin boards are not reliable enough, a more detailed definition of the information circulation workflow is needed. Bulletin boards could be used to deliver information for which there is no other official route.

As the information is exchanged between distinct companies (main contractors and partners) continuously and massively it is not satisfactory only to retrieve the information; it should also be possible to integrate it to the systems of the partner. The information exchange between outside companies is mainly in two areas:

- Exchange of product data (for example design documents): The most practical way is to exchange the data as document files. It is preferred that both the companies use the same tools for the creation and modification of the documents. If there is no need to modify the document viewer tools can be used.

- Product “events”: exchange of orders, delivery of documents or components. The integration would help in planning the production at the subcontractors.

The project contractor and the subcontractors normally have their own operating systems which do not automatically discuss together. Thus making the orders in a database may be done in basically two ways: setting the order in the database of the main contractor (“project net”) or setting it primarily in the database of the subcontractor. If the data is not exchanged between the systems it is available neither to the project management to follow the state of purchases nor to the manufacturer to manage and plan the production.

There is no single answer to which should be the primary system to be used: it depends on the companies and systems, the other contacts and co-operation needs. From the viewpoint of the project manager the simplest way would be to have the data primarily in the central project database.

On the other hand, advanced systems of subcontractors could also offer more services to the project contractor for the purchasing: the internet site of the subcontractor may present the product assortment and offer facilities to make orders. In some cases it is/ will be even possible to view the manufacturing schedule of the subcontractor, set the order in and follow it. The latter requires close co-operation relations and will not be open to all companies.

However, if between two companies the data is saved in the system of the subcontractor, how can the main contractor automatically have the same data in the project database? On the other hand, if the procedure saves the data to the "project net", how can the subcontractor automatically combine it with the other orders coming from different projects and customers? If the collaboration works in a continuous bilateral network the problem should be easier to solve than in temporary virtual enterprises in which the partners may be involved in many separate networks with varying methods of data exchange (n-n –relationships).

9.3.6 Knowledge accumulation and support for improvement activities

Continuous improvement includes different kinds of activities. A project tool or an information system is not the key point in the development actions, but can support them by accumulating knowledge, collecting and offering information. If the project execution creates data about the project activities, lead times, delays and costs, the performance of co-operating partners, quality problems and results, this information could be used in different ways to support the development:

- the experience data could be refined to identify problem areas in the project process or the co-operation partners,
- the experience data could be used for organizational learning, offering a selected set of data which is open to all project managers or team members of all previous projects,
- the experience could also be used to modify the project templates or models used at the project planning phase.

The project management toolset may offer functions for

- the definition of performance indicators for projects
- presentation, search, classification and analysis of data
- the documentation of development activities.

9.3.7 Maintenance of the project workbench

Since the project manager operates not only in a local office it may be necessary to export part of the project data to his/her portable computer to be available outside the information networks. In addition, functions to import the project data back to the project main database may be needed.

The project management workbench uses a set of basic structures and parameters to guide the operation in projects. The project task templates or models linking the product and project configurations to each other are examples of these. The models cannot be static and it must be possible to modify them. The same applies for other generic items, for example user roles and their rights. As the ways of working in networks change, there may become new roles and the user rights may change.

There are different ways of establishing a support tool from the model maintenance point of view. If the objective is to give very detailed support then also many changes are needed as the operating environment or working methods are changed. On the other hand, if the support is minimized everything must be defined again in each project. Thus a balance should be found where the support is adequate but not too subject to changes.

10. Conclusions

The paper reviews part of the research performed in Globeman21 project. The objective of this work has been on developing tools and methods for one-of-a-kind manufacturing in distributed environment. The main emphasis has been on supporting delivery project management. The research is based on an industrial case in which a demonstrator system was developed to evaluate the end user needs (Karvonen & Jansson 1999). It was discovered that the management of the vast project information is the prerequisite for efficient project management, also contributing to achieving the proactive and distributed management.

The support for the information management can be given on different automation levels: offering easy access to the information as such, refining and integrating pieces of it or adding even more intelligence as models, templates, rules or automated pieces of workflow. These functions support not only the project manager but also the distributed team. As the need for the presentation of the information is valid for all the project data the "low level support" levels of displaying and refining information are most often more significant than the more intelligent tools for restricted tasks.

In most project-oriented companies there are information systems which partly cover the needs of the project management system described here. One problem in many cases is that the information, which should be handled and viewed together, is saved in different systems and not easily available for comparison or combinations. Another problem may be that the same information is saved in many systems and when it is modified several operations are needed. This takes time and may cause errors. The same problem is present with the information presented and distributed only in paper format.

The implementation of an information system for project management purposes is thus an information integration task; it does not mean that all the previous systems should be necessarily discarded and replaced by new systems. If the required information already exists in the operative systems it is enough to have the access to these systems and to present the information in an illustrative way.

There are different fields to be considered in developing the management of distributed one-of-kind manufacturing projects. The implementation of information systems to support the activities is not a stand-alone task; it must be linked to the corresponding process and network. In the lifecycle terminology the lifecycles of network, virtual enterprise and product (GERAM 1998, Vesterager et al. 1999) perhaps also product generation are considered. In addition to the product delivery process itself also the management process and control principles must be defined.

Since the main concern in this study has been on the project manager support functions, the viewpoint has been that of the project contractor. The architectures or infrastructures of the distributed systems have not been considered in general. The project environment means temporary relations between diverse companies having different kinds of capabilities and needs for information exchange within the project and operating in several networks. This domain of dynamic inter-enterprise management will be the subject of forthcoming research.

At present the utilisation of the possibilities offered by internet for distributed operations is growing fast. The first versions are in practical use and the software providers in the field are exporting the functions to web interfaces. As the wireless services develop further it is expected that they will be a media for a part of the support functions.

The development of information systems to support the project manager does not eliminate the need for the project manager expertise or human interaction in the project. To achieve common commitment the project team needs mutual interaction, agreed working methods and trust. If the openness of the information is implemented properly it also helps the project team to work together more efficiently.

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One-of-a-kind manufacturing, for example deliveries of process plants, fulfil the characteristics of projects and thus also the generic project management practices may be applied for them. In the present operation environment the activities are distributed in a network; for each delivery a “virtual enterprise” is created to realise the customer order. The distribution makes the management of the delivery project both important and difficult. In many cases it is necessary to distribute also part of the management by assigning the responsibility of compound elements or tasks to trusted partners.

The distribution increases the importance of information exchange and communication in the project. The project information is important both for the project manager and for efficient project operations. Since the sources and users of the information are distributed, tools and channels to exchange and share the information in a user-friendly and acceptable way are needed.

The paper describes typical manufacturing project and management processes and identifies the information utilised in them. As the role of information is crucial, requirements for supporting the information management in delivery projects and a general specification of support functions of a project workbench are given. The work is based on the development of a project workbench demonstrator in co-operation with the project managers and team members of a Finnish project contractor.</td></tr>
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