4 Product Development Process

In the previous chapters we examined the fundamentals on which design work should be built to best advantage. They form the basis of a systematic approach which practising designers can follow, regardless of their speciality. The approach is not based on one method but applies known and less well known methods where they are most suitable and useful for specific tasks and working steps.

4.1 General Problem Solving Process

An essential part of our own problem solving method involves step-by-step *analysis* and *synthesis*. In it we proceed from the *qualitative* to the *quantitative*, each new step being more concrete than the last.

In the following sections we propose plans and procedures that should be regarded as mandatory for the general problem solving process of planning and designing technical products, and as guidance for the more concrete phases of the design process. These plans and procedures assist in identifying what, in principle, has to be done, but of course they must be adapted to specific problem situations.

All procedural plans proposed in this book have to be considered as *operational guidelines for action* based on the pattern of technical product development and the logic of stepwise problem solving. According to Müller [4.17], they are process models that are suitable for describing in a rational way the approach necessary to make complex processes comprehensible and transparent.

Thus, these procedural plans are not descriptions of *individual thinking processes* as described in Section 2.2.1, and are not determined by personal characteristics. In a practical application of these procedural plans, the operational guidelines for action blend with individual thinking processes. This results in a set of individual planning, acting and controlling activities based on general procedures, specific problem situations and individual experiences.

As discussed in Section 2.2.1, the suggested procedural plans are meant to be guidelines and not rigid prescriptions. However, they have to be regarded as essentially sequential because, for example, a solution cannot be evaluated before it has been found or elaborated. On the other hand, the procedural plans have to be adapted to specific situations in a flexible manner. It is, for example, possible to leave out certain steps or order them in another sequence. It may be necessary or useful to repeat certain steps at a higher information level. Furthermore, special procedures (adapted from the more general plans proposed here) may be appropriate in specific product domains.

Given the complexity of the product development process and the many methods that have to be applied, not adopting a procedural plan would leave designers with an unmanageable number of possible approaches. It is therefore necessary for designers to learn about the design process and the application of individual methods, as well as the working and decision making steps proposed in the procedural plans.

The activity of planning and designing was described in Section 2.2.3 as information processing. After each information output, it might become necessary to improve or increase the value of the result of the last working step. That is, to repeat the working step at a higher information level, or to execute other working steps until the necessary improvements have been achieved.

Repeating working steps is the process of *iteration* by which one approaches a solution step-by-step until the result seems satisfactory. The so-called iteration loop can also be observed in the basic thinking processes, for example in the TOTE model (see Section 2.2.1). Such iteration loops are almost always required and occur continuously within and between steps. The reasons for this are that the interrelationships are often so complex that the desired solution cannot be achieved in one step and that information is frequently needed from a subsequent step. The iteration arrows in procedural plans clearly indicate this fact. In subsequent chapters, strategies for reducing, or even avoiding, such iteration loops are presented. It is therefore important that the procedural plans proposed are not considered rigid and purely sequential.

A systematic approach aims to keep the iteration loops as small as possible in order to make design work effective and efficient. It would be a disaster, for example, if the design team had to start again at the beginning having reached the end of a product development. This would correspond to an iteration loop covering the whole of the product development process.

The division in working and decision making steps ensures necessary and permanent links between *objectives*, *planning*, *execution* (organisation) and *control* [4.3, 4.29]. With these links, we can, following Krick [4.15] and Penny [4.21], construct a basic scheme for the general problem solving process (see Figure 4.1).

Every task involves an initial *confrontation* of the problem, which involves elucidating what is known or not (yet) known. The intensity of this confrontation depends on the knowledge, ability and experience of the designers, and on the particular field in which they are engaged. In all cases, however, more detailed *information* about the task itself, about the constraints, about possible solution principles and about known solutions for similar problems is extremely useful since it clarifies the precise nature of the requirements. This information can also reduce confrontation and increase confidence that solutions can be found.

Next comes the *definition* phase, where the essential problems (the crux of the task) are defined on a more abstract plane, in order to set the objectives and main constraints. Such solution-neutral definitions open the way to an unconstrained

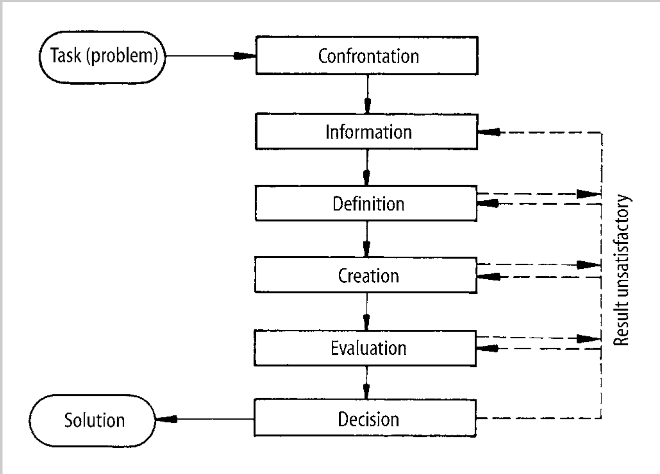

Figure 4.1. General problem solving process

search for solutions because this abstract definition encourages a search for more unconventional solutions.

The next step is *creation*, where solutions are developed by various means and then varied and combined using methodical guidelines. If the number of variants is large, there must also be an *evaluation* which is then used to select the best variant through a *decision*. Because each step of the design process must be evaluated, evaluation serves as a check on progress towards the overall objective.

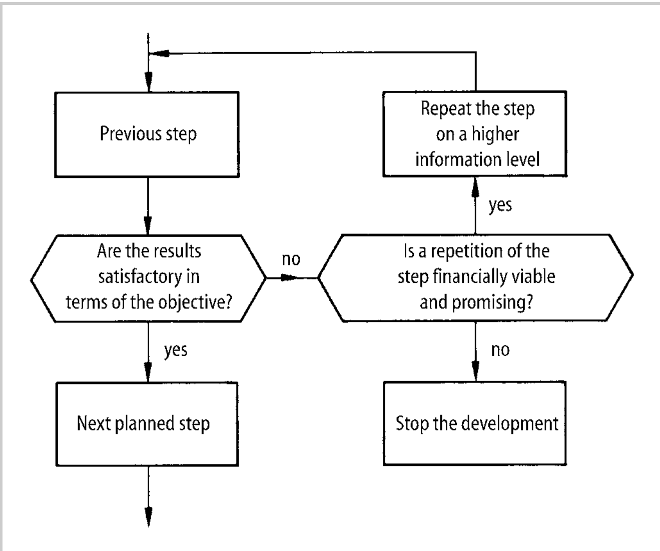

Figure 4.2. General decision making process

Decisions involve the following considerations (see Figure 4.2):

- If the result from the previous step meets the objective, the next step can be started.
- If the results are incompatible with the objective, the next step should not be taken.
- If resources permit repetition of the previous step (or if necessary several preceding steps), and good results can be expected, the step must be repeated on a higher information level.
- If the answer to the previous question is no, the development must be stopped.

Even if the results of a particular step do not meet the objectives, they might nevertheless prove interesting if the objectives are wholly or partly changed. In this case, there should be an investigation to see whether the objectives can be changed or if the results can be used for other applications. This whole process, leading from confrontation through creation to decision, must be repeated in each successive, increasingly concrete, phase of the design process.

4.2 Flow of Work During the Process of Designing

Today's conditions for product design and development demand careful planning of:

- the required activities for the proposed project
- the timing and scheduling of these activities
- the project and product costs.

The activities and their durations strongly depend on the type of task, in particular whether the task is for an original, adaptive or variant design.

4.2.1 Activity Planning

The flow of work during the process of designing has been described in both general terms as well as domain and product-specific terms in VDI Guidelines 2221 and 2222 [4.24, 4.25] (see Figure 1.9). In line with these guidelines, the next sections provide an extensive description of this flow of work, focused on mechanical engineering. The description is essentially based on the fundamentals of technical systems (see Section 2.1), the fundamentals of the systematic approach (see Section 2.2), and the general problem solving process (see Section 4.1). The aim is to adapt the general statements to the requirements of the mechanical engineering design process and to incorporate the specific working and decision making steps for this domain. In principle, the planning and design process proceeds from the planning and clarification of the task, through the identification of the required functions, the elaboration of principle solutions, the construction of modular structures, to the final documentation of the complete product [4.18].

In addition to the planning of the specific tasks described in the guidelines mentioned above, it is useful and common to divide the planning and design process into the following *main phases*:

- Planning and task clarification: specification of information
- Conceptual design: specification of principle solution (concept)
- Embodiment design: specification of layout (construction)
- Detail design: specification of production.

As we will see later on, it is not always possible to draw a clear borderline between these main phases. For example, aspects of the layout might have to be addressed during conceptual design, or it might be necessary to determine some production processes in detail during the embodiment phase. Neither is it possible to avoid backtracking, for example during embodiment design when new auxiliary functions may be discovered for which principle solutions have to be found. Nevertheless, the division of the planning and control of a development process into main phases is always helpful.

The working steps proposed for each of the main phases are termed the *main working steps* (see Figure 4.3). The results of these main working steps provide the basis for the subsequent working steps. Many lower level working steps are required to realise these results, such as collecting information, searching for solutions, calculating, drawing and evaluating. Each of these working steps is accompanied by indirect activities such as discussing, classifying and preparing. The *operational main working steps* listed in the procedural plans proposed in this chapter are considered to be the most useful strategic guidelines for a technical domain. Guidelines that are not listed include, for example, those related to basic problem solving, collecting information and verifying results. This is because they can usually only be recommended in relation to a specific problem and a particular designer. Recommendations for such elementary working steps will, where possible, be given in the sections describing individual methods and those dealing with practical applications.

After the main phases, and some of the more important main working steps, *decision making steps* are required. The decision making steps listed are the main ones—those that end a main phase or working step, which after an appropriate assessment of the results, allow the main flow of work to proceed. It is also possible, because the result of a decision making step was unsatisfactory, that certain steps will have to be repeated. The smallest possible iteration loop is desirable.

Again, the individual test and decision making steps (see for example the TOTE model in Section 2.2.1) that are required for every single action have not been listed separately. This would have been impossible because such decisions are determined by the approach of individual designers and by particular problem situations.

The decision to stop a development that ceases to be viable, as discussed in Section 4.1, is not mentioned explicitly in the individual decision making steps of the procedural plans. One should, however, always explicitly consider this possibility because an early and clear decision to halt a hopeless situation will, in the end, minimise disappointment and cost.

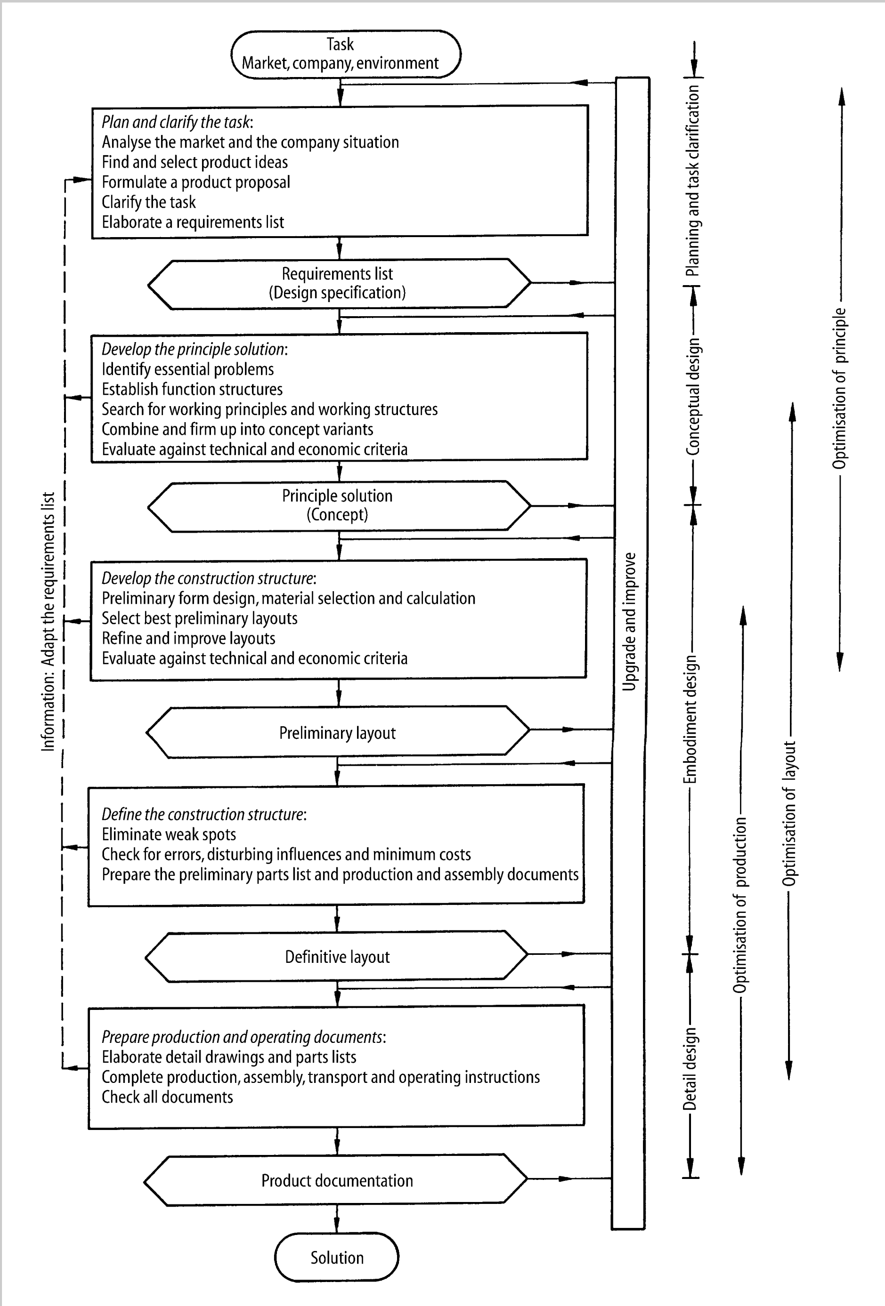

Figure 4.3. Steps in the planning and design process

In all cases procedural plans should be applied in a flexible manner and adapted to the particular problem situation. At the end of each main working and decision step, the overall approach should be assessed and adjusted if necessary.

The four main phases are outlined below.

1. Planning and Task Clarification

The product development task is given to the engineering department by the marketing department, or a special department responsible for product planning, see also Sections 3.1 and 5.1.

Irrespective of whether the task is based on a product proposal stemming from a *product planning* process or on a specific customer order, it is necessary to clarify the given task in more detail before starting product development. The purpose of this *task clarification* is to collect information about the requirements that have to be fulfilled by the product, and also about the existing constraints and their importance.

This activity results in the *specification of information* in the form of a *requirements list* that focuses on, and is tuned to, the interests of the design process and subsequent working steps (see Section 5.2). The conceptual design phase and subsequent phases should be based on this document, which must be updated continuously (this is indicated by the information feedback loop in Figure 4.3).

2. Conceptual Design

After completing the task clarification phase, the conceptual design phase determines the principle solution. This is achieved by abstracting the essential problems, establishing function structures, searching for suitable working principles and then combining those principles into a working structure. Conceptual design results in the specification of a *principle solution* (concept).

Often, however, a working structure cannot be assessed until it is transformed into a more concrete representation. This concretisation involves selecting preliminary materials, producing a rough dimensional layout, and considering technological possibilities. Only then, in general, is it possible to assess the essential aspects of a solution principle and to review the objectives and constraints (see Section 2.1.7). It is possible that there will be several principle solution variants.

The representation of a principle solution can take many forms. For existing building blocks, a schematic representation in the form of a function structure, a circuit diagram or a flow chart may be sufficient. In other cases a line sketch might be more suitable, and sometimes a rough scale drawing is necessary.

The conceptual design phase consists of several steps (see Chapter 6), none of which should be skipped if the most promising principle solution is to be found. In the subsequent embodiment and detail design phases it is extremely difficult or impossible to correct fundamental shortcomings of the solution principle. A lasting and successful solution is more likely to spring from the choice of the most appropriate principles than from exaggerated concentration on technical details.

This claim does not conflict with the fact that problems may emerge during the detail design phase, even in the most promising solution principles or combinations of principles.

The solution variants that have been elaborated must now be evaluated. Variants that do not satisfy the demands of the requirements list have to be eliminated; the rest must be judged by the methodical application of specific criteria. During this phase, the chief criteria are of a technical nature, though rough economic criteria also begin to play a part (see Sections 3.3.2 and 6.5.2). Based on this evaluation, the best concept can now be selected.

It may be that several variants look equally promising, and that a final decision can only be reached on a more concrete level. Moreover, various form designs may satisfy one and the same concept. The design process now continues on a more concrete level referred to as embodiment design.

3. Embodiment Design

During this phase, designers, starting from a concept (working structure, principle solution), determine the construction structure (overall layout) of a technical system in line with technical and economic criteria. Embodiment design results in the specification of a *layout*.

It is often necessary to produce several *preliminary layouts* to scale simultaneously or successively in order to obtain more information about the advantages and disadvantages of the different variants.

After sufficient elaboration of the layouts, this design phase also ends with an evaluation against technical and economic criteria. This results in new knowledge on a higher information level. Frequently, the evaluation of individual variants may lead to the selection of one that looks particularly promising but which may nevertheless benefit from, and be further improved by, incorporating ideas and solutions from the others. By appropriate combination and the elimination of weak spots, the best layout can then be obtained.

This *definitive layout* provides a means to check function, strength, spatial compatibility, etc., and it is also at this stage (at the very latest) that the financial viability of the project must be assessed. Only then should work start on the detail design phase.

4. Detail Design

This is the phase of the design process in which the arrangement, forms, dimensions and surface properties of all of the individual parts are finally laid down, the materials specified, production possibilities assessed, costs estimated, and all the drawings and other production documents produced [4.28] (see also [4.26]). The detail design phase results in the *specification of information* in the form of *production documentation*.

It is important that designers should not relax their vigilance at this stage, otherwise their ideas and plans might change out of all recognition. It is a mistake to think that detail design poses subordinate problems lacking in importance or interest. As we said earlier, difficulties frequently arise from lack of attention to detail. Quite often corrections must be made during this phase and the preceding steps repeated, not so much with the overall solution in mind, as to improve assemblies and components as well as reduce costs.

5. Overall Design Process

In the flow diagram (see Figure 4.3), the main themes are:

- optimisation of principle
- optimisation of layout
- optimisation of production.

Clearly the description above is a generalisation of actual processes. In practice a clear distinction between the working steps and their results cannot always be made, nor is it necessary to do so. However, it is useful for designers to be aware of the main process flow and tasks described in order to plan their work and to avoid forgetting something.

Figure 4.3 does not include the production of models and prototypes because the information they supply may be needed at any point in the design process and so cannot be fitted into any particular slot. In many cases, it is even necessary to develop models and prototypes during the conceptual phase, particularly when they are intended to clarify fundamental questions in, say, the precision engineering, electronics and mass production industries. Due to the one-off nature of heavy and process engineering, the cost and time required to produce prototypes normally makes them uneconomic or infeasible. However, it is possible to test parts of the proposed plant or equipment by building partial prototypes within existing plant and equipment or by using specific test facilities. In batch production it is common to produce prototypes well before production starts and also to undertake a pre-production run to ensure that production will run smoothly. These pre-production products can still be sold.

Figure 4.3 also does not indicate when work has to be subcontracted, because this depends upon the type of product.

The execution of orders is usually part of product development, although in the case of size ranges and modular products it can take place quite late in the process.

If on receiving an order, only existing documents are used, and only production instructions, subcontractor orders, parts lists, etc., need to be compiled, no product development is required. So apart from tender drawings, layout drawings and assembly plans, no further design work is needed, and in many cases these drawings and plans can be generated automatically using variant design software.

Upon looking at Figure 4.3, and after reading about the methods described in the following chapters, practising designers may well object to the process on the basis that they lack the time to go through every one of the many steps. They should bear in mind that:

- Most of the steps are performed in any case—albeit unconsciously—although they are often carried out too quickly, leading to unforeseen consequences.

- This deliberate step-by-step procedure, on the other hand, ensures that nothing essential has been overlooked or ignored, and is therefore indispensable in the case of original designs.
- In the case of adaptive designs, it is possible to resort to time-tested approaches and to reserve the procedure described for where it offers special benefits; for example, when improving a specific detail, in which case the steps should be undertaken focusing on this detail.
- If designers are expected to produce better results, then they must be given the extra time the systematic approach demands, although experience has shown that only a little extra time is needed for a stepwise procedure.
- Scheduling becomes more accurate if the step-by-step method is followed rigorously.

4.2.2 Timing and Scheduling

Products will only be successful when they:

- satisfy the customer needs (requirements)
- reach the market at the right time
- are sold at the right price.

This section focuses on the second prerequisite, because designers often underestimate the importance of time-to-market and are not familiar with the methods and tools used for timing and scheduling. We only introduce the basic approaches. Details have to be obtained from the literature.

Two constraints determine the planning difficulty:

- the project or design result must be finished at a certain point in time, and intermediate results are required on specific dates
- not every task can be executed by every member of the team, i.e. there is a resource constraint.

Network planning is one of the most important planning tools [4.7,4.8]. A network plan is used to estimate the overall project length and resource requirements. The graphical representation shows the logical links between the required project tasks and the resources assigned to these tasks.

Creating a network plan involves performing three main steps:

- Structure analysis to identify and describe the links and dependencies between the project tasks.
- Time analysis to identify the necessary duration for each task along with a feasible starting date for each of the main steps.
- Resource analysis to allocate the various tasks to individual team members. In the first instance this should be based on their competences, followed by their

Table 4.1. Procedure for creating a network plan

	Activity	Explanation
1.	Determine product structure	In general the structure of an existing similar product is adapted
2.	Determine the tasks necessary to create the individual product elements	For every product element and for the overall product, the tasks include the following to an appropriate level: ● solution finding ● investigation ● embodiment ● calculation
3.	Establish logical and temporal dependencies between individual tasks	Dependencies between tasks have to be identified and documented as unambiguous IF–THEN statements: e.g. IF the shaft diameter is determined, THEN the shaft–hub connection can be fixed
4.	Establish the duration of the tasks	● interview those with relevant experience ● compare with similar tasks ● document completed tasks ● estimate
5.	Fix milestones (these are used to check whether the work and schedule have been achieved; a milestone trend analysis allows the prediction of the success or failure of a project)	**Types of milestones:** **Event-driven:** The content of a milestone has to be defined precisely. A milestone is reached when the available working results meet the defined content of that milestone **Application:** Mostly used as the final milestone for the design of an assembly **Time-driven:** The milestone is reached at a certain point in time or after a certain time interval has elapsed **Application:** For large tasks when it is not possible to define clear intermediate results **Point of no return:** Event or point in time after which the results achieved must not be changed further **Application:** Securing intermediate results, e.g. against customers changing requirements **Review:** Point in time at which clearly defined results have to be explicitly signed off or released **Application:** The embodiment of expensive and complex assemblies or components is signed off by production or, in some cases, by the customer
6.	Determine necessary and possible float times for the tasks	Float times serve to manage risk in order to avoid endangering the project plan when delays occur and are applied, in particular, for novel tasks
7.	Create network plan (usually using special software tools: e.g. Microsoft Project, Super-Project-Expert)	A network plan shows in graphical and tabular form all of the dependencies between the tasks and milestones, and is used to determine the course of a project
8.	Create project calendar	The project calendar shows the exact number of working days available for the duration of the project
9.	Select resources and allocate them to tasks in the network plan	The selection is based on the required competencies and the availability of resources during the planned period of the project
10.	Create a resource calendar and allocate to the network plan	For every employee an individual calendar is created showing his or her available working time during the duration of the project: holidays, training days, etc. must be taken into account

Table 4.1. (continued)

	Activity	Explanation
11.	Run through the plan	After the resources and the individual calendars are allocated to the network plan, the first run-through is undertaken
12.	Evaluate the plan	• Can the project milestone be achieved? • What is the critical path? (i.e. the sequence of tasks with no float times that determines the overall duration of the project)
13.	Optimise the plan	The plan can be optimised and corrected by: • increasing the resources available • moving deadlines • reducing the number of tasks • changing the sequence of tasks • altering the content of the tasks
14.	Sign off the plan	The project plan is released through the signature of the manager responsible, and, where appropriate, by the customer
15.	Monitor the project	All project parameters, such as deadlines, costs and risks are continuously monitored and reported

availability, which can be limited because they may be absent due to training courses, illness, holidays, etc., or because they have been allocated to other projects.

In general the product structure is used as the basis for planning the task structure. The product structure determines the main assembly groups and components that have to be designed and, as a consequence, the majority of the tasks.

Table 4.1 shows the procedure for creating a network plan and the individual steps. Figure 4.4 shows part of a network plan, in this case a Gantt chart. The individual tasks are represented by bars. Their dependencies result from logical or possible working sequences, e.g. input/output requirements, where one task must have been completed before the next can be started.

A network plan not only shows project duration, resource requirements and allocation of team members to tasks, but also float times and the critical path of the project. The float times indicate how much the start or end of a task or series of tasks can be delayed without jeopardising the overall lead time of the project. The critical path contains those tasks that have no float times and therefore determine the overall duration of the project.

4.2.3 Planning Project and Product Costs

The cost price is the basis for determining the selling price and is therefore crucial to the success of the product. The cost price is influenced by the production costs and the associated project costs. Design and development are the costliest items contributing to the project cost, so engineering departments carry a great responsibility.

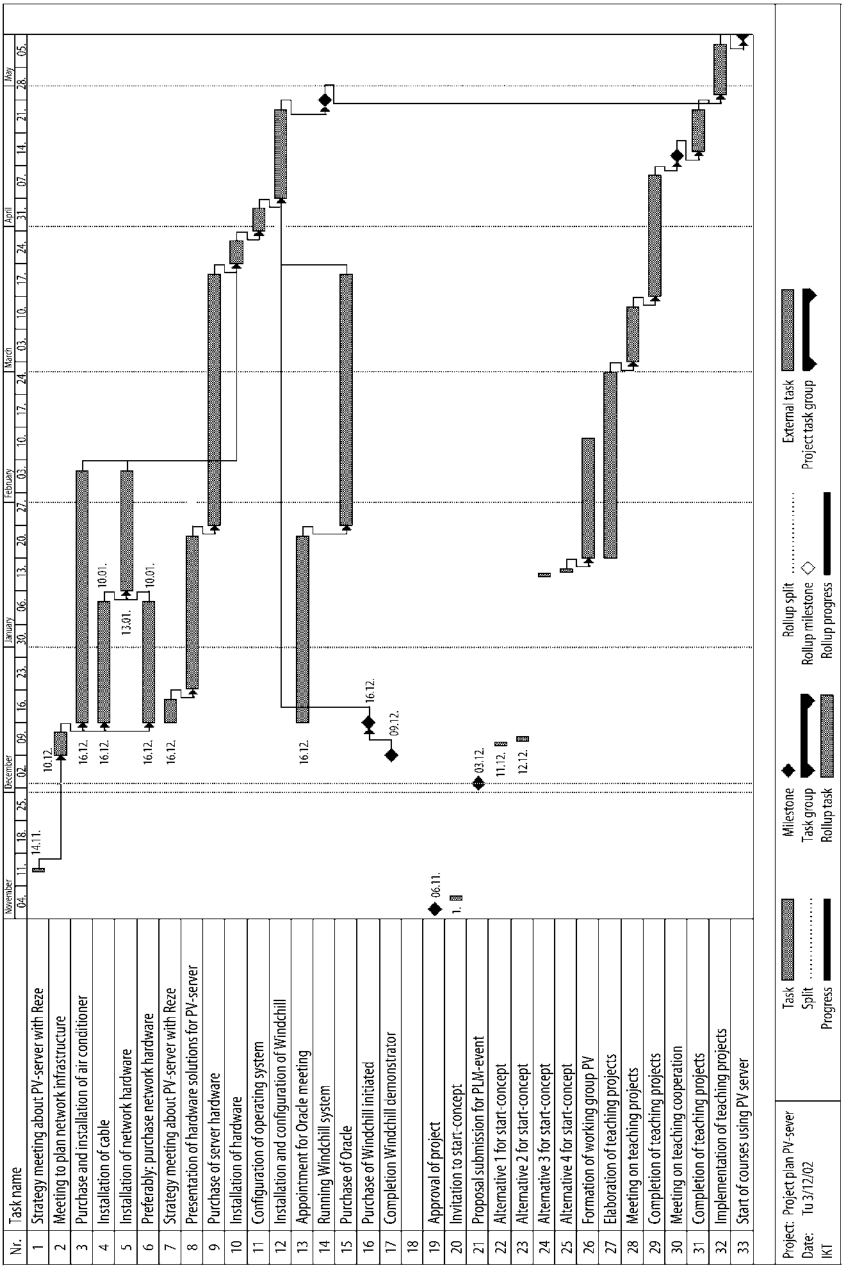

Figure 4.4. Example of a network plan

In order to meet the target cost price, engineering departments not only have to keep production costs to a minimum (see Chapter 11 for more details), but also the design and development costs. Depending on the batch size, the latter costs can represent a large share of the cost price.

To estimate the design and development costs, a network plan can also be used because the main costs incurred by engineering departments are staff costs. Support costs, such as facilities, CAD systems, external consultants, etc., are usually much lower. Using the network plan, costs can be assigned to the allocated resources using the appropriate hourly rate. The distribution of the costs with time can be represented by a cost plan [4.9], which is important when estimating the project budget.

4.3 Effective Organisation Structures

4.3.1 Interdisciplinary Cooperation

Designers cannot work independently of their environment—they depend on the results produced by others and others depend on their results. They are members of their departments, which in turn are parts of the company. Only the coordinated activities of all participants will lead to a satisfactory overall result [4.11, 4.22]. To achieve this, the responsibilities, tasks, etc., for every individual are specified by the organisational and operational structures:

- The *organisational structure* specifies the responsibilities and tasks for individuals, departments and standing committees, and relates these in a hierarchy.
- The *operational structure* specifies the various procedures.

The design and development process is made more efficient through the following actions:

- reducing inner iterations, i.e. repetition of the same activity within a working step
- reducing outer iterations, i.e. jumping back to a working step that has already been completed or even repeating a design phase
- omitting working steps
- executing working steps in parallel.

In particular, the last action has the potential to reduce the overall project time significantly. To achieve these four actions, the following prerequisites must be met:

- The product has to be structured in such a way that the properties of its systems, subsystems and system elements can be modelled precisely and unambiguously during every step of the process. Chapter 9 proposes some possible product structures.
- The interfaces between the process steps have to be defined precisely and unambiguously.
- The process steps have to be independent.

When these prerequisites have been met and interdisciplinary teams formed, then *Simultaneous or Concurrent Engineering* can be introduced. Simultaneous or Concurrent Engineering involves goal-oriented, interdisciplinary (interdepartmental) collaboration and parallel working throughout the development of the product, the production process and the sales strategy. It covers the total product life cycle and requires firm project management [4.1]. Experiences of its application in industry can be found in [4.12, 4.14]. Figure 1.4 highlights the intensive information flows that occur between departments. In a simultaneous engineering process the activities of the various departments run in parallel or at least have significant overlap. Intensive contacts with customers are encouraged, many suppliers are integrated in the process, see Figure 4.5 [4.5, 4.13, 4.23], and the product is monitored until the end of its working life.

For the duration of the project, a team is formed consisting not only of members of the design and development department but also those from other departments involved in the product creation process. This team, which is formed as early as possible, is led by a project manager, works independently, but has to report directly to the Board of Management or Head of Development. Departmental boundaries are thereby transcended. The team can operate as a virtual team; that is, without a visible organisational form. Characteristics of team structures and their importance can be found in [4.6, 4.27]. The objectives of this type of organisation and working procedure are:

- shorter development times
- faster product realisation
- reduction of product and product development costs
- improved quality.

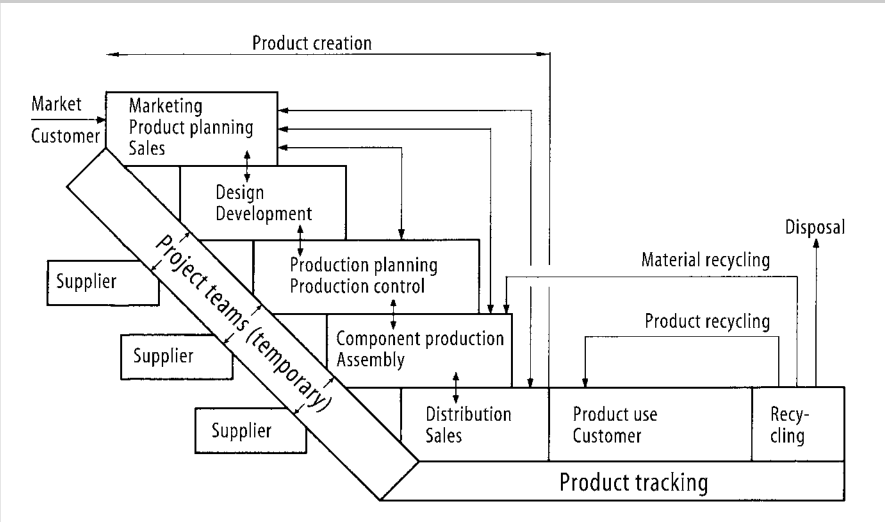

Figure 4.5. Product creation and tracking processes using Simultaneous Engineering, showing the overlapping activities of different disciplines, the formation of a project team and close contact with customers and suppliers

Simultaneous or Concurrent Engineering changes a designer's work as follows [4.20]:

- Working in an interdisciplinary team requires the adaptation of language and terminology.
- A closer, more direct exchange of information takes place through the early involvement of other departments and disciplines.
- More electronic information and communication technologies are used, e.g. data processing systems, CAD, multimedia, etc.
- A project management process with schedules and milestones is imposed so that design work has to be structured more systematically.
- Activities are run in parallel and therefore have to be coordinated accordingly.
- Individual responsibility for the assigned problems and tasks has to be accepted in line with team decisions.
- Contact with suppliers and customers becomes more intense.

It is useful to build a small core team with the experts who are responsible for design, production planning, marketing and sales. The composition of the team depends on the particular problem and type of product. This core team is complemented by experts from quality, assembly, electronics, software, recycling, etc., as and when needed and who may only participate for short periods of time. In such a team the knowledge and experience from neighbouring disciplines (see Figure 4.6) are more or less automatically incorporated into the project. This integration of a wide range of expertise significantly improves the realisation of the project goals and the ability to meet the constraints, as discussed in Section 2.1.7 and in accordance with Figure 2.15.

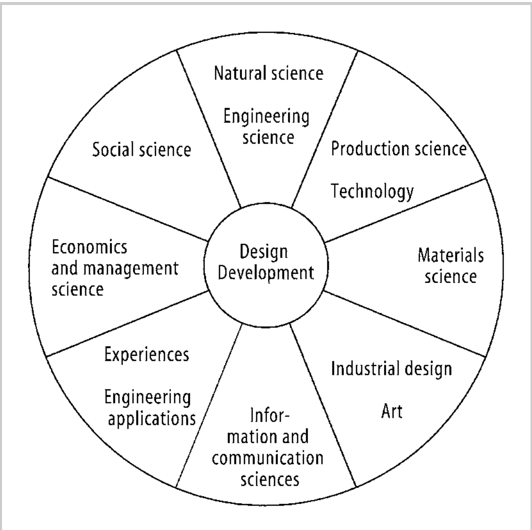

Figure 4.6. Related knowledge domains that support design and development

The advantages of an interdisciplinary team are:

- increased availability of knowledge and mutual stimulation
- better control of the product and the process—achieved by questioning issues and identifying contradictions
- increased motivation through direct participation and information sharing
- immediate responses to situations without the need to seek and wait for approval from higher levels in the hierarchy.

When the focus is on lean production, information and decision chains must become shorter. To facilitate this it is often necessary to build temporary project groups whose members are released from the departmental hierarchy for the duration of the project. The designer who previously worked within the confines of his discipline-based department, where he or she could easily call upon colleagues for advice and support, now has to work much more independently and within less familiar surroundings. To work in such project teams, a number of skills are required that go beyond the usual discipline-based ones [4.19,4.20] (see Figure 4.7). These issues must be taken into account when selecting the project leader.

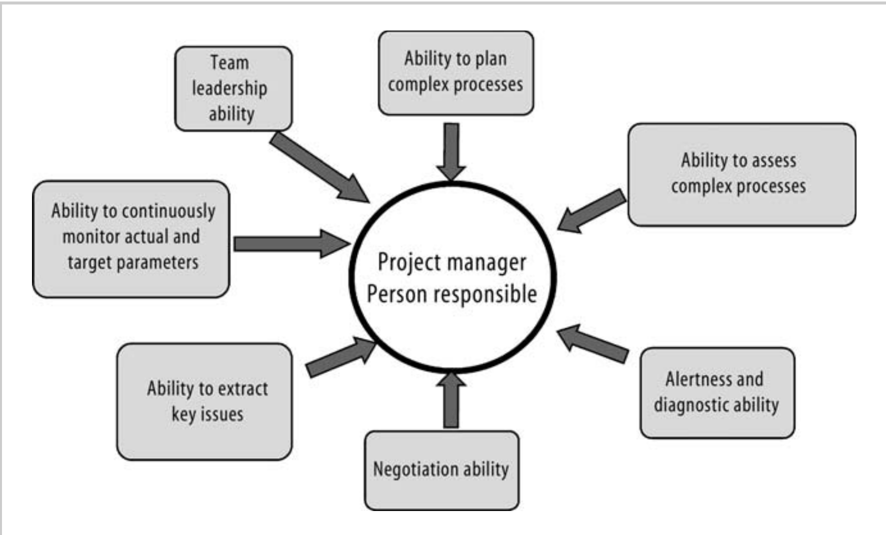

Figure 4.7. Abilities required of project managers

4.3.2 Leadership and Team Behaviour

Strong project leadership is necessary when developing new products in teams that are independent of departmental structures. Project leaders must have a good knowledge of the relevant technology and design methods as well as the characteristics of good problem solvers (see Section 2.2.2). Only then are they able to lead a team of experts from different fields to achieve the project goals and to cope with the tasks assigned to them [4.20].

Project leaders and their teams can use the systematic approach presented in this book as an effective means of support. They can use it to initiate and check their approach, to select suitable methods, define decision steps (milestones), and apply established design principles. Depending on the problem, project leaders and teams need to be willing to adapt their approaches and methods on the basis of importance and urgency. Project leaders must not be dogmatic in their leadership style, must utilise the manifold skills in the team, must provide every team member with individual freedom of action, and must demonstrate decisiveness when it matters. Leadership involves:

Providing timely information by:

- pointing out deviations from the project plan as early as possible
- managing information in a balanced and uniform manner.

Steering individual activities carefully in line with a systematic approach by:

- planning the main project parameters such as deadlines, costs and resources
- pursuing these project targets
- estimating the effort and consequences of any changes
- updating the project plan when necessary.

Representing the team effectively by:

- managing reporting and documentation
- taking personal responsibility for team presentations, etc.

Fostering team building and mutual trust by:

- making and encouraging decisions in difficult situations.

If project leaders cannot fulfil these requirements, then the simultaneous engineering approach will be difficult to adopt.

Team behaviour also plays an essential role. Teamwork benefits product development and individual team members (see Section 4.3.1), however it can also give rise to the following problems [4.2]:

- groups or teams that work together for a long time tend to oversimplify
- control of team effectiveness can decline
- teams begin to conform, which can lead to the protection of competences and the overestimation of capabilities
- groups who have worked together successfully for a long time develop a self-confidence that is not always justified
- within a team one may find opinionated individuals who dominate others and who need careful management
- some team members may sit back and not pull their weight.

In addition to adopting an understanding leadership style, these problems can be addressed specifically by creating small teams, encouraging an open dialogue, and, if necessary, removing or adding team members. Ideally, teams should be dissolved when their project goals have been achieved.

Dörner and Badke-Schaub [4.2, 4.10] have written about the effectiveness of groups and teams in comparison with individuals. Although general statements are difficult to make, it appears that group opinions settle at a relatively high level. This means that results are never as good as those of the best individuals, but also never as bad as those of the worst individuals. An idea or the work of an individual can stand out from that of the team, but can also be significantly worse.

This implies that surprising proposals from individuals should not be suppressed. On the contrary, these should be developed to a point where a clear comparison with the team result is possible. In a team one cannot rely on, or even expect, valuable individual original contributions to arise, so opportunities should be created to encourage them. Team building does not automatically guarantee good solutions. Company culture and leadership style remain fundamental for effective teamwork and successful individual work.