5 Task Clarification

5.1 Importance of Task Clarification

The design task is generally presented to the design and development department in one of the following forms:

- as a development order (from outside or from the product planning department in the form of a product proposal)
- as a definite order
- as a request based on, for instance, suggestions and criticism by sales, research, test or assembly staff, or originating in the design department itself.

The task description contains not only statements about the product, such as its functionality and performance, but also statements about deadlines and cost targets. The design and development department now faces the problem of identifying the requirements that determine the solution and embodiment and formulating and documenting these quantitatively as far as possible. In order to achieve this, the following questions need to be answered in close cooperation with the client or proposer:

- What are the objectives that the intended solution is expected to satisfy?
- What properties must it have?
- What properties must it not have?

The result or this process is a *requirements list*. This document thus represents the specification against which the success of the design project can be judged.

In so far as this has not already been done in product planning (see Section 3.1), the design and development department should undertake the situation analysis described in 3.1.4 in order to specify the product situation and to identify future developments.

A useful method used to support the preparation of the requirements list is *Quality Function Deployment* (QFD) (see Section 10.5). QFD helps to translate customer wishes into product requirements.

5.2 Setting Up a Requirements List (Design Specification)

The main working steps required to set up a requirements list are shown in Figure 5.1. The procedure involves two stages. In the first stage the obvious requirements are defined and recorded. In the second stage these requirements are refined and extended using special methods.

The following sections describe the contents and format of a requirements list, along with the individual working steps.

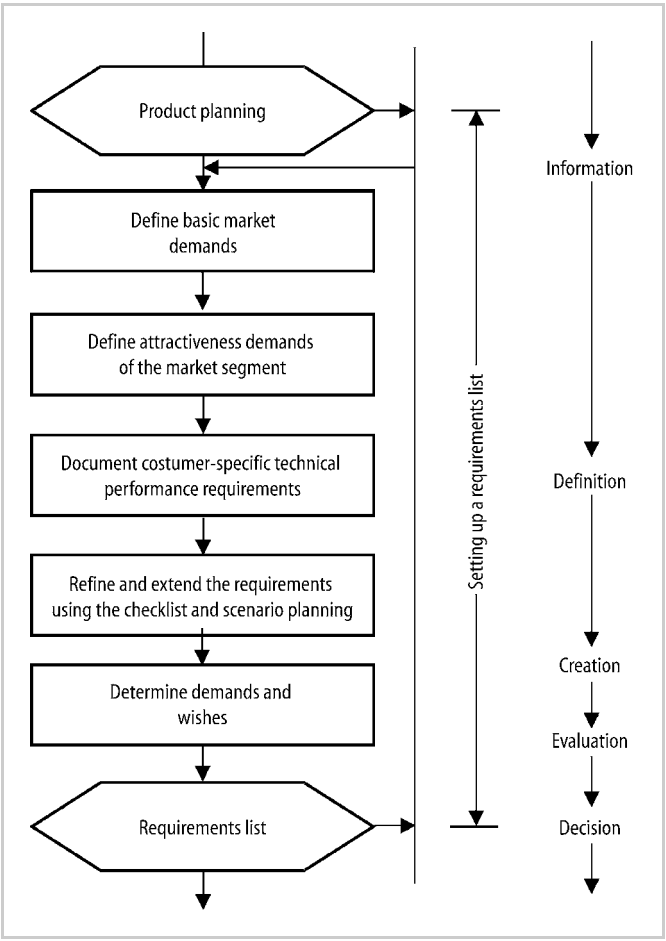

Figure 5.1. Main working steps required to set up a requirements list

5.2.1 Contents

When preparing a detailed requirements list it is essential to clearly elaborate the goals and the circumstances under which they have to be met. The resulting requirements must be identified either as demands or wishes.

Demands are requirements that must be met under all circumstances; in other words, if any of these requirements are not fulfilled the solution is unacceptable (for instance such qualitative demands as "suitable for tropical conditions", "splashproof", etc.). Minimum demands must be formulated as such (for example $P > 20$ kW; $L < 400$ mm).

Wishes are requirements that should be taken into consideration whenever possible, perhaps with the stipulation that they only warrant limited increases in cost, for example, central locking, less maintenance, etc. It is advisable to classify wishes as being of major, medium or minor importance [5.4].

The distinction between demands and wishes is also important at the evaluation stage, since selection (see Section 3.3.1) depends on the fulfilment of demands, while evaluation (see Section 3.3.2) is only performed on variants that already meet the demands.

Even before a certain solution is adopted, a list of demands and wishes should be set up and the quantitative and qualitative aspects tabulated. Only then will the resulting information be adequate:

- Quantity: All data involving numbers and magnitudes, such as number of items required, maximum weight, power output, throughput, volume flow rate, etc.
- Quality: All data involving permissible variations or special requirements, such as waterproof, corrosionproof, shockproof, etc.

Requirements should, if possible, be quantified and, in any case, defined in the clearest possible terms. Special indications of important influences, intentions or procedures may also be included in the requirements list, which is thus an internal digest of all the demands and wishes expressed in the language of the various departments involved in the design process. As a result, the requirements list not only reflects the initial position but, since it is continually reviewed, also serves as an up-to-date working document. In addition, it is a record that can, if necessary, be presented to the Management Board and the sales department so that they may make their objections known before the actual work is started.

5.2.2 Format

The requirements list should at least contain the following information in a structured format (see also Figure 5.2).

- user: company or department
- project or product name
- requirements labelled as demands or wishes
- person responsible for each requirement
- date of issue for the overall requirements list
- date of last change
- version number and/or index number
- page number.

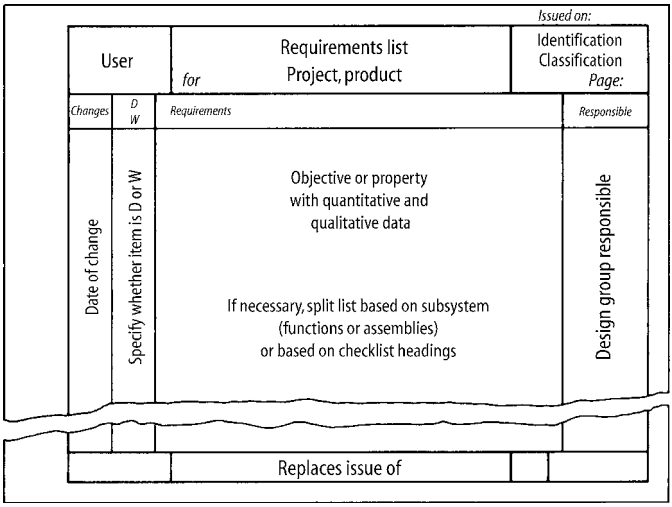

Figure 5.2. Layout of a requirements list

It is helpful if the format of the requirements list becomes a company standard so that it can be used, elaborated and adopted by as many departments as possible. Figure 5.2 is thus no more than a suggestion that can, of course, be modified at will.

It may prove useful to set up the requirements list based on subsystems (functions or assemblies) where these can be identified, or else based on checklist headings (see Figure 5.3). With established solutions, where the assemblies to be developed or improved are already determined, the requirements list must be arranged in accordance with these: special design groups are usually put in charge of the development of each assembly. With motor cars, for instance, the requirements list can be subdivided into engine, transmission and bodywork development.

It is extremely useful to *record the source* of demands and wishes. It is then possible to go back to the proposers of requirements and to enquire into their actual motives. This is particularly important when the question arises of whether or not the demands can be changed in the light of subsequent developments.

Any *changes in*, and *additions to*, the original task that may result from a better understanding of solution possibilities or from possible changes in emphasis must always be entered into the requirements list, which will then reflect the progress of the project at any particular time.

Responsibility for this work is placed on the chief designer. The updated requirements list should be circulated among all departments concerned with the development of the product (management, sales, accounts, research, etc.). The requirements list should only be changed or extended due to a decision of those in charge of the overall project and by following a formal change management procedure.

Main headings	Examples
Geometry	Size, height, breadth, length, diameter, space requirement, number, arrangement, connection, extension
Kinematics	Type of motion, direction of motion, velocity, acceleration
Forces	Direction of force, magnitude of force, frequency, weight, load, deformation, stiffness, elasticity, inertia forces, resonance
Energy	Output, efficiency, loss, friction, ventilation, state, pressure, temperature, heating, cooling, supply, storage, capacity, conversion.
Material	Flow and transport of materials. Physical and chemical properties of the initial and final product, auxiliary materials, prescribed materials (food regulations etc)
Signals	Inputs and outputs, form, display, control equipment.
Safety	Direct safety systems, operational and environmental safety.
Ergonomics	Man-machine relationship, type of operation, operating height, clarity of layout, sitting comfort, lighting, shape compatibility.
Production	Factory limitations, maximum possible dimensions, preferred production methods, means of production, achievable quality and tolerances, wastage.
Quality control	Possibilities of testing and measuring, application of special regulations and standards.
Assembly	Special regulations, installation, siting, foundations.
Transport	Limitations due to lifting gear, clearance, means of transport (height and weight), nature and conditions of despatch.
Operation	Quietness, wear, special uses, marketing area, destination (for example, sulphurous atmosphere, tropical conditions).
Maintenance	Servicing intervals (if any), inspection, exchange and repair, painting, cleaning.
Recycling	Reuse, reprocessing, waste disposal, storage
Costs	Maximum permissible manufacturing costs, cost of tooling, investment and depreciation.
Schedules	End date of development, project planning and control, delivery date

Figure 5.3. Checklist for setting up a requirements list

5.2.3 Identifying the Requirements

As a rule, the first requirements list undertaken is the most difficult to set up. Experience greatly facilitates the compilation of subsequent ones. After a relatively short period, several examples become available that can be used as the starting point for subsequent requirements lists.

The main issue associated with setting up a requirements list is the quantity and quality of the documents and data that are supplied with the design task. Depending on the branch of engineering, not all the expected product properties

will have been defined and documented. The rest of them are expected by the customers but not made explicit, i.e. they are implicit requirements. The following questions therefore need to be answered:

- What is the problem really about?
- Which implicit wishes and expectations are involved?
- Do the specified constraints actually exist?
- What paths are open for development?

It is therefore important for the design and development department to understand the customers or the market segment involved. The basis of the requirements list is often a contract that has been signed with a customer. This contract usually includes the agreed product properties and performance data, product liability regulations, and the guidelines that have to be applied.

In a first exploratory step, the statements and requirements in the contract are translated into product-relevant parameters that designers and engineers can apply. This is relatively straightforward to do because the product specification in a contract involves explicit requirements. A bigger problem is how to deal with the implicit requirements; although they are not expressed they still have a very negative impact if they are not fulfilled. What effects, for example, do statements such as "simple maintenance" have on the embodiment of the product, and how can such statements be formulated as specific requirements? How difficult it is to formulate a requirements list depends on the type of customer and, in principle, two types can be distinguished:

- *anonymous customers:* these include a particular market segment, those identified by the sales department without a customer order, and those identified by the product planning department.
- *specific customers:* these not only include individual customers who place an order, but also market segments that are served by many companies with similar products in which requirements have become standardised, e.g. those for "compact cars" and "family cars". Although the actual customers in such cases are anonymous, they can, in effect, be treated as specific customers.

According to Kramer [5.3], some specific types of requirement can be formulated for each type of customer.

Basic requirements are always implicit requirements, i.e. they are not articulated by the customer. Their fulfilment is self-evident and vital for the customer. Success or failure of a product is determined by these requirements. For example, for a follow-on product the customer generally expects energy consumption and operating costs to be reduced. It is essential for the design and development department to recognise the importance of these implicit requirements. The sales department or product management must supply information about these requirements, along with the thoughts and expectations of the customers.

Technical performance requirements are explicit requirements. They are articulated by the customer and can usually be specified precisely. For example, a new

engine may have to have 15 kW of power and weigh not more than 40 kg. Such concrete values are used by customers when comparing competing products. The importance of the individual parameters is determined by the customers themselves.

Attractiveness requirements are again implicit requirements. Customers are usually not aware of these; however, they are used to differentiate between competing products. In general customers are not willing to pay higher prices for these additional product properties. Consider an example from a motor car where the number of standard colours and the available combinations of external and internal colour schemes are such requirements.

5.2.4 Refining and Extending the Requirements

Two methods have been developed to refine and extend the requirements list defined thus far:

- follow a checklist
- create scenarios.

The checklist shown in Figure 5.3 is a generic one based on ideas described in Section 2.1.7. The items in this list are checked against the existing task and its requirements in order to obtain further requirements. A further checklist can be found in Ehrlenspiel's book [5.1].

When creating scenarios, the product life from production to disposal is considered and sketched out. For every stage, a scenario is developed and the following questions asked:

- What might happen to the product? Examples: What kind of state might it find itself in? How might it be treated and used? Who might use it or come into contact with it? Where might it be used?
- How should the product react? Examples: What level of tolerance to failure should be built in? How should dangerous situations be avoided?

The answers to these questions are used to formulate further product requirements. Most of these requirements will not be very specific, i.e. they cannot be translated into the product parameters that determine solutions or embodiments. For example, the previously mentioned statement "simple maintenance" needs to be specified in more detail. Kramer [5.3] proposes the following three-step procedure to achieve this.

First step (statement)

- Customer's need: simple maintenance.

Second step (development)

- Customer's requirements:
  1. Provide long maintenance interval

2. Enable simple maintenance
3. Make maintenance procedures easy to learn.

Third step (refinement)

- Provide long maintenance interval:
  1. Maintenance interval at least 5 000 operating hours
  2. Grease cams every 10 000 operating hours.
- Enable simple maintenance:
  1. Fit maintenance access covers with manual locks
  2. Fit cams with lubricating points that fit standard grease guns
  3. Leave space for oil drip tray
  4. Provide locating features to assist when refitting access covers.
- Make maintenance procedures easy to learn:
  1. Add a separate section in the operating manual describing maintenance procedures
  2. Provide labels indicating the locks that need to be undone for maintenance
  3. Indicate the directions of the maintenance operations with etched arrows.

The results of the third step are then added to the requirements list.

When clarifying the task, one should start by collecting the essential functions and the existing task-specific constraints with respect to the energy, material and signal transformations. When all of the information is available, it must be grouped, ordered and labelled.

In 5.2.1 we pointed out the essential differences between demands and wishes. In many cases it is clear from the outset whether a requirement is a demand or a wish. However, a definitive assignment is required before the requirements list is released. If necessary, further information should be collected. Wishes should be formulated such that their weighting can be established. Initially it is often useful to express such weightings qualitatively rather than quantitatively, because the estimates often change as the understanding of the task develops.

5.2.5 Compiling the Requirements List

In the light of arguments advanced in this chapter, the following general method of compiling a requirements list can now be recommended:

1. Identify the requirements:
   - Check the customer contract or the sales documents for technical requirements and define and document them.
   - Refer to the items of the checklist (Figure 5.3) and determine the quantitative and qualitative data.
   - Create scenarios that consider all stages in the product's life and thus derive further requirements.

- Refine by asking:
  - What objectives must the solution satisfy?
  - What properties must it have?
  - What properties must it not have?
- Collect further information.
- Specify demands and wishes clearly.
- If possible, rank wishes as being of major, medium or minor importance.

2. Arrange the requirements in a clear order:
   - Define the main objective and the main characteristics.
   - Split into identifiable subsystems, functions, assemblies, etc., or in accordance with the main headings of the checklist.
3. Enter the requirements list on standard forms and circulate among interested departments, licensees, directors, etc.
4. Examine objections and amendments and, if necessary, incorporate them into the requirements list.

Once the task has been adequately clarified, and the relevant departments are satisfied that the listed requirements are technically and economically attainable, the way is clear for the conceptual design phase.

5.2.6 Examples

Figure 5.4 shows a requirements list for a printed circuit board positioning machine, illustrating the main characteristics of the content and the format of requirements lists. It has been structured according to the main characteristics given in Figure 5.3. The requirements have been split into demands and wishes, and, where possible and necessary, quantified. Modifications and amendments with their dates are also shown. The latter were the result of an intensive discussion of a first draft of the requirements list (first version 21st April 1988).

Requirements lists based on the above recommendations are provided in Figures 6.4, 6.27 and 6.43 as further examples.

5.3 Using Requirements Lists

5.3.1 Updating

In principle, requirements lists should be binding and complete. However, initially a requirements list is always provisional because, as the design process proceeds, it grows and changes. Any attempt to formulate all possible requirements at the start of a project will fail and would cause considerable delays. Looking at the inputs

Siemens		Requirements list for a printed circuit board positioning machine	Issued on 27/04/88 Page: 1
Changes	D W	Requirements	Responsible
		1. Geometry: dimensions of the test sample	Langner's group
		Circuit board:	
	D	Length = 80 – 650 mm	
	D	Breadth = 50 – 570 mm	
	W	Height = 0.1 – 10 mm	
	D	Required hight = 1.6 – 2 mm	
	W	Clearance between basic grid boards ≤ 120 mm	
	D	'Clamping area' ≤ 2 mm (edges of the board)	
		2. Kinematics:	
27/04/88	D	Precise positioning of the test sample	
27/04/88	D	Minimum of 2 mm displacement of the test sample normal to the board	
27/04/88	D	Feedback to transfer position	
	W	separate stations for input and output	
	D	Design of clearance zone	
	W	Minimum handling time (as fast as possible)	
		3. Forces:	
	D	Weight of the test sample ≤ 1.7 kg	
27/04/88	W	Maximum weight of the test sample ≤ 2.5 kg	
		4. Energy:	
	D	Electrical and /or pneumatic (6 – 8 bar)	
		5. Material:	
	D	Free from rust	
	D	Isolation between test sample and testing device	
27/04/88	W	Thermal expansion of testing device adjusted to expansion of printed circuit	
27/04/88	D	Consideration of influence of temperature	
27/04/88	D	Temperature range: 15–40 °C	
27/04/88	D	Humidity: 65 %	
27/04/88	W	Circuit boards: epoxy-fiberglass sheet	
27/04/88	D	No condensation	
		6. Safety:	
27/04/88	D	Operator Safety	
		7. Production:	
		Consideration of tolerance build up	
		8. Operation:	
	D	No contamination inside the testing device	
	D	Destination: production line	
		9. Maintenance:	
	W	Maintenance intervall > 10^6 test operations	
		10. Schedule:	
	D	Embodiment finished by July 1988	
		Replaces issue of 21/04/88	

Figure 5.4. Requirements list for a printed circuit board positioning machine (Siemens AG)

and outputs of individual working steps in the design process, the reasons become clear. For example, in the final stages of designing a motor car, the thicknesses of all of the individual layers of body paint need to be known. However, to develop the concept, these data are not relevant. The paintwork requirements therefore do not have to be specified until much later in the process.

Thus, working with binding yet provisional requirements lists takes into account the fact that not all of the data and requirements are known or have to be known at the beginning of a design process. Only those requirements that are absolutely necessary in order to be able to proceed to the next working step need to be documented. At the start of a project, it is important to specify those parameters and properties that:

- define the particular concept
- influence the product structure
- determine the overall embodiment of the product.

The contents of a requirements list therefore depend on the state of the product design and the stage of the design process. The list has to be continuously amended and extended. Managing requirements lists in this way avoids having to deal with questions and requirements before they can be adequately answered and specified.

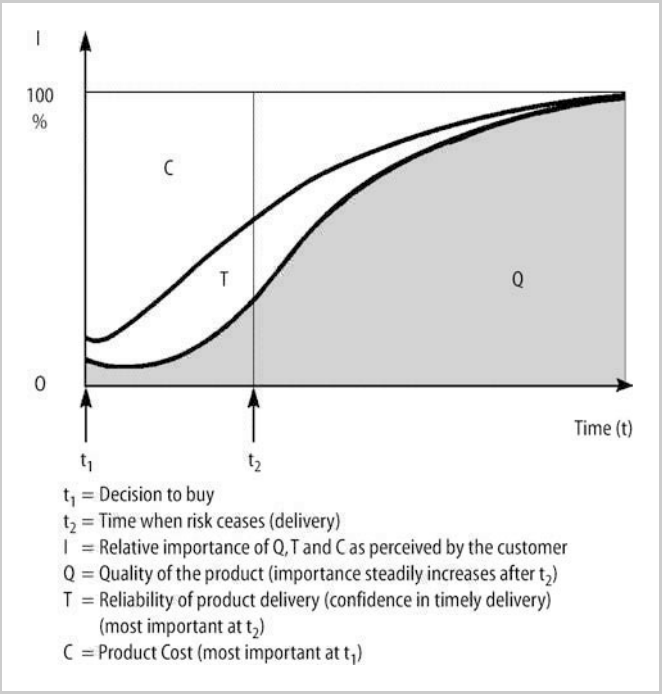

Figure 5.5. Changing appreciation of product quality by the customer

Product requirements frequently change with time, during both product creation and product use.

During Product Creation, customers often change their demands and wishes. This happens when customers gain new knowledge and understanding and when the planned application has been extended. This is typical of capital equipment because of its long development process. For railway rolling stock, for example, it is possible that during the development process the rail network has been extended with the consequence that specified powers and capacities are no longer sufficient.

During product use, customer appreciation of the product can change and, as a consequence, the requirements and their relative importance can also change. For example, the longer a product is in service, the more important quality issues such as long maintenance intervals and reliability become, see Figure 5.5 [5.3].

The fact that requirements can change must be considered when setting up a requirements list. A mutually satisfactory requirements management process is therefore essential in order to ensure good and lasting relations between a company and its customers.

5.3.2 Partial Requirements Lists

It is often beneficial for specialist areas or departments of a company to prepare so-called "partial requirements lists" documenting only their particular requirements. This removes the need for the design and development department to spend time collecting more information and data than are strictly relevant to them, see Figure 5.6 [5.2].

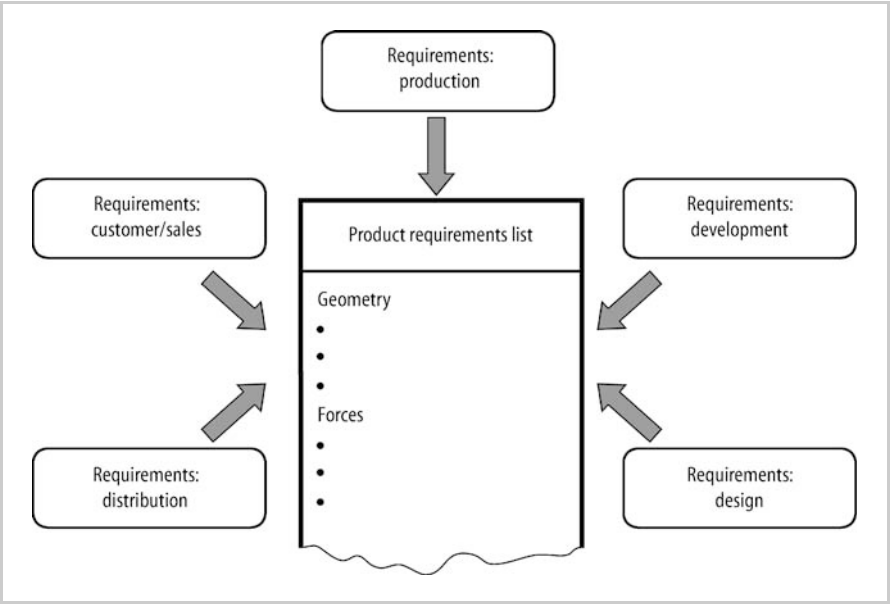

Figure 5.6. Product requirements list compiled from partial requirements lists

The product requirements list is a compilation of all of the partial requirements lists. An important role of project management is to ensure that the partial requirements lists cover all areas and are compatible with each other. Modern engineering data management systems [5.5] support their efficient administration and editing.

5.3.3 Further Uses

Even when the design is not original, and the solution principle and layout are fixed so that nothing more than *adaptations* or *dimensional changes* need to be made in a familiar area, orders should nevertheless be executed on the basis of requirements lists, which can then take the form of templates or questionnaires. These should be constructed in such a way that information for electronic data processing and quality control can be read off directly. As a result, requirements lists become sources of information for direct action.

Beyond that, requirements lists, once compiled, are an invaluable *source of information* about the required or desired properties of the product, and hence extremely helpful for further developments, negotiations with suppliers, etc. Setting up requirements lists for existing products can also provide a very valuable source of information for the subsequent development and rationalisation of those products.

The examination of a requirements list during project meetings or before assessing various designs is an extremely useful procedure. All of those involved are placed in possession of all of the available information and all salient evaluation criteria are brought home to them.

Requirements lists are an important basis for knowledge management systems. Stored in such systems, requirements lists provide a very valuable source of knowledge about previous projects that can often be reused.

5.4 Practical Application of Requirements Lists

In the last few years it has been shown that, at least for original designs, the formulation of a requirements list is a very efficient method for solution development and has been broadly adopted by industry. When used in practice, however, the following issues often arise:

- *Obvious requirements*, such as low-cost production, ease of assembly, are often not included in the requirements list. One should take care that these issues are both addressed and expressed precisely.
- In an early stage of the project it is not always possible to make *precise statements* in the requirements list. The statements have to be amended or corrected during the design and development process.
- A *stepwise development* of the requirements list is very useful when tasks are poorly defined. In these cases the requirements should be formulated more precisely as soon as possible.

- During the formulation of requirements lists or related discussions, *functions* or *solution ideas* are often mentioned. This is not wrong. They can encourage a clearer formulation of the requirements and even lead to the identification of new requirements. The solution ideas or proposals generated should be recorded so that they can be used later in the systematic search for solutions. However, they should not enter—and possibly bias—the requirements list.
- The identification of *deficiencies* and *failures* can initiate requirements that must then be formulated in a solution-neutral way. Failure analysis is often the starting point for a requirements list.
- For *adaptive* or *variant designs*, designers should still make requirements lists for themselves, even when the task is small.
- Setting up requirements lists should not be formalised too strictly. *Guidelines* and *forms* are only a *means* to prevent important issues from being forgotten and to provide a supporting structure. If one deviates from the recommendations in this book, one should a least consider the main characteristics and distinguish between demands and wishes.