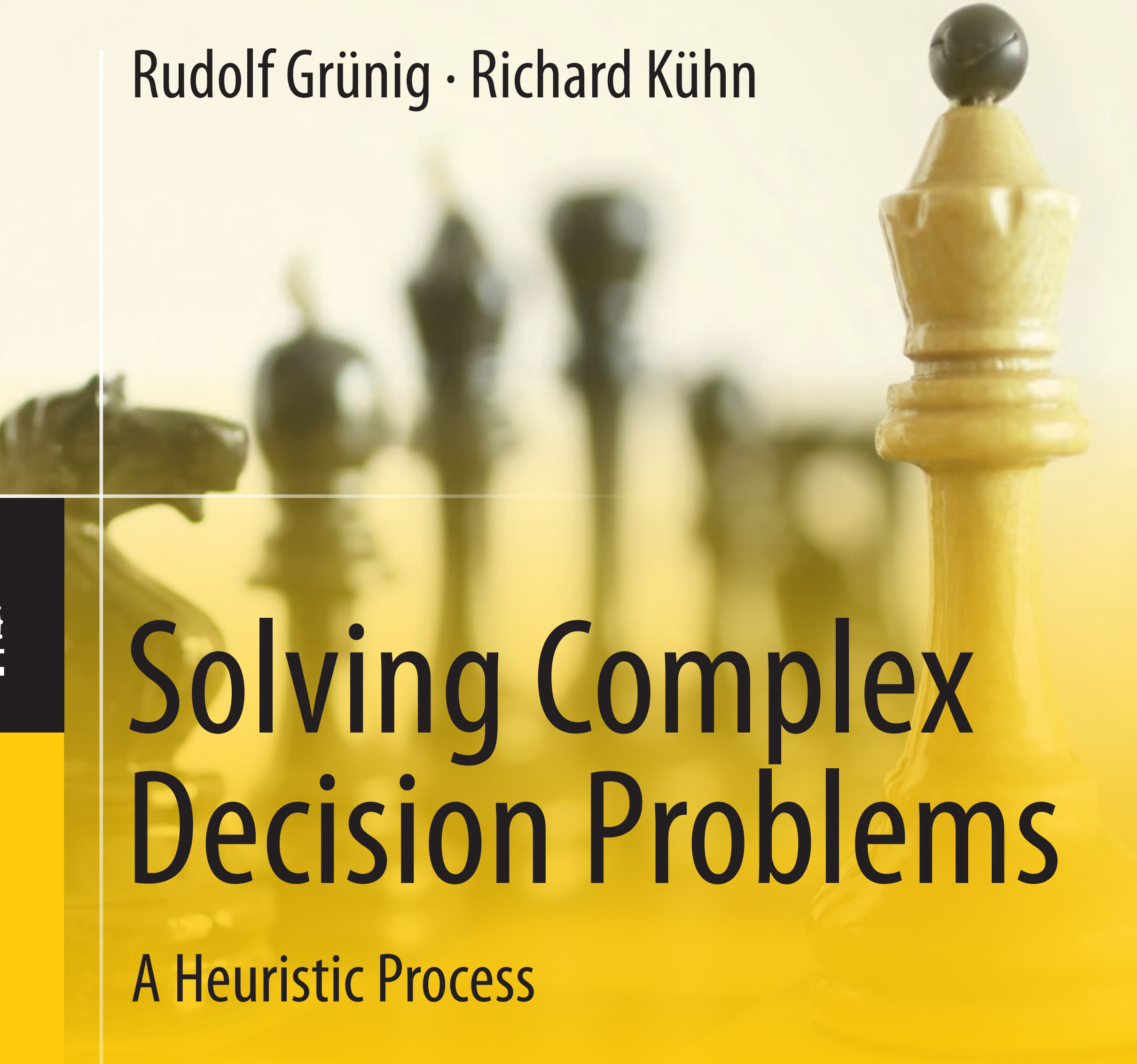
Rudolf Grünig · Richard Kühn



Solving Complex Decision Problems

A Heuristic Process

Fifth Edition

Springer

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Preface

The focus of this book is the process for solving complex decision problems. The explanations place great emphasis on analyzing the problem, developing the options, defining the decision criteria, and determining the consequences. This is based on the fundamental belief that the overall evaluation of the options and the decision are no longer a significant challenge if they are based on a sound foundation.

The text of the fifth edition has been optimized with the aim of simplifying the recommendations for action and thus of improving their applicability. At the same time, it has been ensured that the explanations reflect the complexity of real, far-reaching decision problems.

Richard Kühn passed away in April 2023. His contributions to the content of this book have been important. Therefore, he remains the co-author of the fifth edition.

Richard Kühn and I co-authored several articles, contributions to encyclopedia, and four books. If the different book editions in different languages are counted individually, this edition is the 42nd oeuvre! This was only possible thanks to the fact that we understood and appreciated each other. In terms of content, besides many agreements there were also different viewpoints. It was the associated discussions that helped us to move forward. Richard Kühn was one of the most important persons in my life. I will never forget him.

I would like to thank Audrey Renggli for preparing the examples for the application of the decision maxims. My greatest thanks go to Tu Le for her excellent work in preparing the manuscript, the figures, and the bibliography.

Biel, Switzerland — Rudolf Grünig
July 2025

Competing Interests The authors have no competing interests to declare that are relevant to the content of this manuscript.

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1 Introduction

"Decision making is only one of the tasks of an executive. It usually takes but a small fraction of his or her time. But to make the important decisions is the specific executive task" (Drucker 2001, p. 19). Making decisions is certainly not a main activity of an executive. It is, however, a vital one. Long-term success or even survival often depends on making at least satisfactory decisions. This usually leads to considerable psychological pressure on the person or group who must make the decision.

The decision-making problems that affect the long-term success and survival of the company are usually complex. This means that, in addition to the psychological pressure associated with such decisions, there is a high degree of difficulty. An at least useful decision requires systematic preparation. Therefore, the main objective of this book is to propose a problem-solving procedure for complex decision problems. The procedure is based on the literature and the practical experience of the authors in dealing with complex problems through consulting mandates and as members of boards of directors. Independently of the specific problem, the proposed procedure enables a systematic approach and thus creates the conditions for at least a satisfactory decision.

This book consists of three parts:

- Part I introduces decision methodology. It defines decision problems, shows how such problems are discovered, and what is meant by rational problem-solving. It also explains what a problem-solving procedure is and distinguishes four types of such procedures.
- Part II presents the general heuristic problem-solving procedure and thus forms the central element of the book. After an overview of the procedure, the individual steps are explained in detail.
- Part III, finally, looks at three special issues. The first concerns the problem of dealing with decision sequences. The second issue is whether additional information should be collected during problem-solving or whether the decision

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should be based on existing information. Finally, the difficulties of collective decisions are discussed, and approaches to overcome them are presented.

In line with its objective, the present book deals comprehensively with all the subquestions associated with the solution of complex decision problems. Therefore, it deals not only with the final evaluation of options, which dominates the content of many popular textbooks on decision-making. Importance is also attached to other tasks that are important for successful problem solving, such as problem discovery, problem analysis, the development of solution options, and the determination of the consequences of the options. Accordingly, mathematical-analytical approaches play a lesser role: the complexity of a decision problem lies to a large extent in its initially unknown structure. Mathematical-analytical models, however, demand well-structured problems and can therefore only be applied once the problem has been structured and thus much of the complexity has been overcome.

The book is intended mainly for decision-makers in companies, nonprofit organizations, and governmental administrations. It is designed as a working tool to help them successfully solve complex problems. However, the book also provides a basis for students to learn to deal with complex problems in a systematic way. It is, therefore, suitable as a practice-oriented teaching aid to introduce decision-making methods in universities and executive courses.

The book can only be useful for practice if it takes the complexity of decision problems seriously and does not attempt to cloak difficulty with simplifications and a lightness of style. As a result, it is not always easy to understand the text. To facilitate the study of the book, the following measures were taken:

- The terms are explained when they are first used. They are then used consistently, even when the ideas of authors who use different terminology are discussed. The most important terms are also found in the glossary.
- Graphics support comprehension.
- The text includes numerous examples that make the explanations easier to understand.
- Finally, scientific questions that are not necessary for the comprehension of the recommended problem-solving methodology have been removed from the "normal" text. Instead, they are presented as insets, which introduce interested readers to the subject matter and to specific literature.

The authors hope that, despite the challenging subject matter, the text is understandable thanks to these measures and is of genuine practical use.

Reference

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Part I

Decision Problems and Problem-Solving Procedures

2 Decision Problems

2.1 Notion of Decision Problem

Decision problems only emerge if a person or group of persons—both referred to as the "actor" in decision methodology—possesses a conscious idea of a desirable state. This target state is almost always different from the current situation or may become different in the future. The actor must therefore act: he must try to reduce or even eliminate the difference between the current situation and the target situation (see Sanders 1999, pp. 7 ff.).

However, the difference between the current and the target situation does not, in itself, constitute a decision problem. A decision problem only arises if there are different ways to reduce this difference. The actor is then faced with the task of developing and assessing different solution options.

This means a decision problem can be understood as:

- A difference between the current and the target situation
- Where at least two solution options exist to deal with it

There exist many human and interpersonal problems, such as depression, deaths of relatives, and conflicts, that do not represent decision problems. The reason is that it is almost impossible to systematically develop and assess options for reducing or eliminating the difference between the current and the target situation for these problems. From the authors' point of view, the difference between the actual and the target situation in companies, nonprofit organizations, and administrations is diametrically different. Here, there are always options for reducing or eliminating the differences—at least if the problem is thoroughly addressed. The actor is therefore faced with the question of which option is best suited. To answer this question, a systematic problem-solving procedure is needed.

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As this book is intended for managers of companies, nonprofit organizations, and administrations, it is always assumed from now on that a discovered problem is a decision problem.

2.2 Types of Decision Problems

A number of criteria can be used to distinguish different types of decision problems (see Rühli 1988, pp. 186 ff.). In the following text, only the criteria relevant later in the book are presented.

Figure 2.1 gives an overview of the most important dimensions and possibilities.

According to the degree of difficulty of the problem—dimension (1)—the distinction can be made between simple and complex decision problems. A complex decision problem is present, according to the authors' understanding, if two or more of the following conditions are fulfilled:

- The actor pursues several goals simultaneously. Some of these goals are not very precisely defined, and it is even possible that contradictions exist between them. As Morieux (2011, p. 78) shows, CEOs in 1955 pursued 4–7 goals. In 2010, 25–40 goals were pursued simultaneously. Accordingly, the actor must use numerous, sometimes qualitative, decision criteria to assess the problem-solving options.
- A high number of decision variables exist to reduce the gap between the current and the target situation. A part of these decision variables has many possibilities. These two factors lead to a very high number of possible solution options. As will be shown in Chap. 8, this does not mean that the actor must develop and assess many options. It is recommended to develop a few but clearly different options that cover the solution space well.
- The future development of several environmental variables is uncertain. This means that the actor must evaluate his solution options based on several possible environmental scenarios.

Figure 2.2 graphically summarizes the characteristics of complex decision problems.

The classification into well-structured and ill-structured decision problems—dimension (2)—comes from Simon and Newell (1958, pp. 4 f.). A problem can be termed well-structured if it can be described so precisely that its solution can be found using an analytical decision-making procedure. If this is not the case, it is an ill-structured problem. A more precise definition of well-structured and ill-structured problems does not make sense here because the conceptual basis for this has not yet been introduced. This will be discussed later in Inset 5.1.

The distinction between choice and design problems—dimension (3)—is suggested by Simon (1966, pp. 1 ff.). Choice problems are problems in which the

Dimension	Possibilities		
(1) Degree of difficulty	Simple decision problem	Complex decision problem	
(2) Problem structure	Well-structured decision problem	Ill-structured decision problem	
(3) Problem character I	Choice problem	Design problem	
(4) Problem character II	Threat problem	Opportunity problem	
(5) Link to other decision problem	Independent decision problem	Decision problem in a decision sequence	
(6) Problem level	Original decision problem	Meta-problems, e.g. information procurement problem	
(7) Type of actor	Decision problems in which an individual decides	Decision problems in which a collective decides	
(8) Decision criteria used	Univalent decision problems based on one decision criteria or several decision criteria with arithmetic ratio	Multivalent decision problems based on several decision criteria without arithmetic ratio	
(9) Ability to predict the development of environment	Certain decision problems based on “a clear enough future” (Courtney et al., 1997, p. 68)	Risk decision problems based on environ-mental scenarios with probabilities of occurrence	Uncertain decision problems with based on environ-mental scenarios without probabilities of occurrence

Fig. 2.1 Dimensions of decision problems and their possibilities

solution options are known from the beginning. If there are three potential suppliers of a specialized machine, the actor has three options. Of these, the best possibility must be chosen. The situation is quite different if new company headquarters must be built. Even if the site has already been decided upon, an almost infinite number of possibilities exist for the structure and layout of the building. The problem can

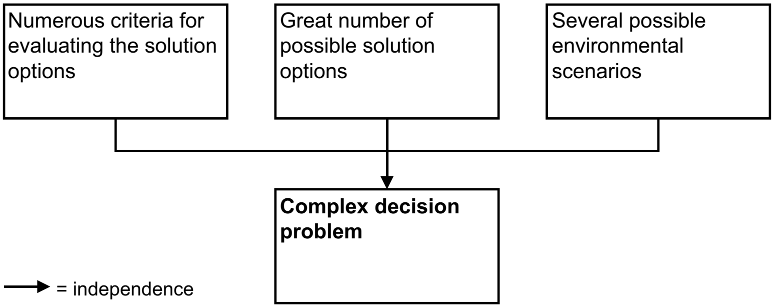

Fig. 2.2 Characteristics of complex decision problems

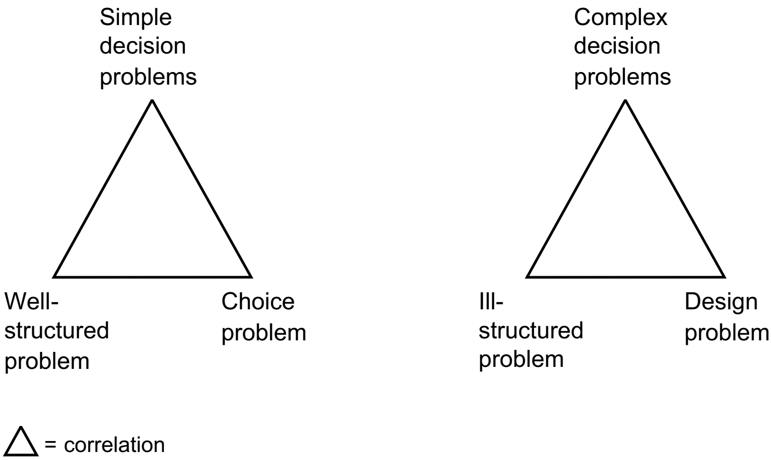

Fig. 2.3 Relationship between dimensions (1), (2), and (3)

only be solved if it is broken down into consecutive and parallel subproblems so that the new headquarters is planned step by step.

The types of decision problems based on dimensions (1)–(3) are related. Simple decision problems are almost always choice problems and often meet the requirements of a well-structured decision problem. In contrast, complex problems are usually design problems and are always ill-structured. Figure 2.3 illustrates these connections.

When speaking in layman's terms of a problem, the overcoming of a danger is meant. This corresponds to a threat problem according to dimension (4). In this book, however, the term "problem" is understood in a neutral way as a difference between the current situation and the target situation. Accordingly, there are not only threat problems but also opportunity problems. A threat problem exists if the target situation can be achieved less well in the future than today. If, on the other hand, there is an opportunity to achieve the target situation better in the future than today, this is referred to as an opportunity problem. Complex problems frequently include both categories of subproblems.

According to dimension (5), a distinction can be made between independent decision problems and problems in a decision sequence. An independent problem exists when the actor selects the best option from a set of solution options. A decision sequence occurs if one or more of the discussed options lead to further decisions later in time. In Part II of the book, complex but independent problems are discussed. Decision sequences are discussed later in Chap. 12 of Part III.

According to dimension (6), two different levels of problems can be distinguished: original decision problems and meta-level problems. Part II deals exclusively with original decision problems. Information collection as an important meta-level problem is discussed later in Chap. 13 of Part III.

According to the type of actor who makes the decision, a distinction can be made in dimension (7) between individual and collective decisions. An individual decision does not exclude the involvement of other people in problem analysis and in the development and evaluation of options. Therefore, a collective decision only exists if several people jointly select the option to be realized and are jointly responsible for it. In Part II of this book, it is assumed that the actor is an individual. Collective decisions are discussed in Chap. 12 of Part III of the book.

If the actor uses only one decision criterion to evaluate the solution options, a univalent decision problem exists according to dimension (8). A univalent decision problem also exists if the actor uses several decision criteria that have an arithmetical relationship between them. This is, for example, the case with net sales and variable costs of products, which together form the contribution margins. However, more often, there are several decision criteria to be used that have no arithmetical relationship between each other, resulting in a multivalent decision problem.

The development of the relevant environment can never be predicted with 100% certainty. Equally, the consequences of the solution options can never be predicted with complete certainty. However, there is often a situation that Courtney et al. (1997, pp. 68 ff.) refer to as “a clear enough future.” In this situation, it is, according to dimension (9), not necessary to define environmental scenarios. Certain consequences are determined, even if the actor knows that the real consequences of the chosen option will slightly deviate from the predicted consequences at the time of the decision. However, the uncertainty in the development of the environment is often so great that, according to Courtney et al. (1997, pp. 68 ff.), “a range of futures” must be expected. In this case, environmental scenarios must be defined. Sometimes they can be assigned probabilities of occurrence. In this case, we speak of a risk decision problem. If no probabilities of occurrence can be assigned to the environmental scenarios, we speak of an uncertain decision problem.

Based on dimensions (8) and (9), six types of decision problems are distinguished in Fig. 2.4.

Dimension (8) / Dimension (9)	**Univalent decision problem**	**Multivalent decision problem**
Certain decision problem	Decision problem under univalence and certainty	Decision problem under multivalence and certainty
Risk decision problem	Decision problem under univalence and risk	Decision problem under multivalence and risk
Uncertain decision problem	Decision problem under univalence and uncertainty	Decision problem under multivalence and uncertainty

Fig. 2.4 Combination of dimensions (8) and (9)

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3 Goal and Problem-Finding Systems as Requirements for the Discovery of Decision Problems

3.1 Discovery of Decision Problems

As the framework in Fig. 3.1 shows, situation assessment is an ongoing task. It is used for the detection of differences between the current and the target situation or of decision problems (see Grünig 2023, pp. 39 ff.). It is important that the assessment of the situation not only focuses on the discovery of threat problems, but that opportunity problems are also searched for with equal intensity.

A difference between the current and the target situation or a decision problem only arises if the actor pursues goals and therefore has a goal system. This means that goal systems are a necessary requirement for the discovery of decision problems.

Differences between current and target situations can be discovered ad hoc. This is the case, for example, when a production manager "discovers" that certain machines are not running during a routine tour, or when a sales manager is faced with an unusually high number of customer complaints. Well-trained and experienced executives can discover problems in an "ad hoc" way. However, the risk remains that important problems will be overlooked, or that problem discovery will take place later than necessary. To reduce this risk, many companies develop and use problem-finding systems. They make it possible to discover decision problems systematically and—in the case of early warning systems—at an early stage. Unlike goal systems, problem-finding systems do not represent a necessary condition for the discovery of decision problems. However, they make an essential contribution, especially in medium-sized and large companies, to the complete and early detection of differences between current and target states.

3.2 Goal Systems

A goal is a target state that is therefore maintained or strived for (Heinen 1976, p. 45). A company's target state nearly always consists of a set of goals, that is, of a goal system. A goal system's elements are rarely all precise, and the system is also

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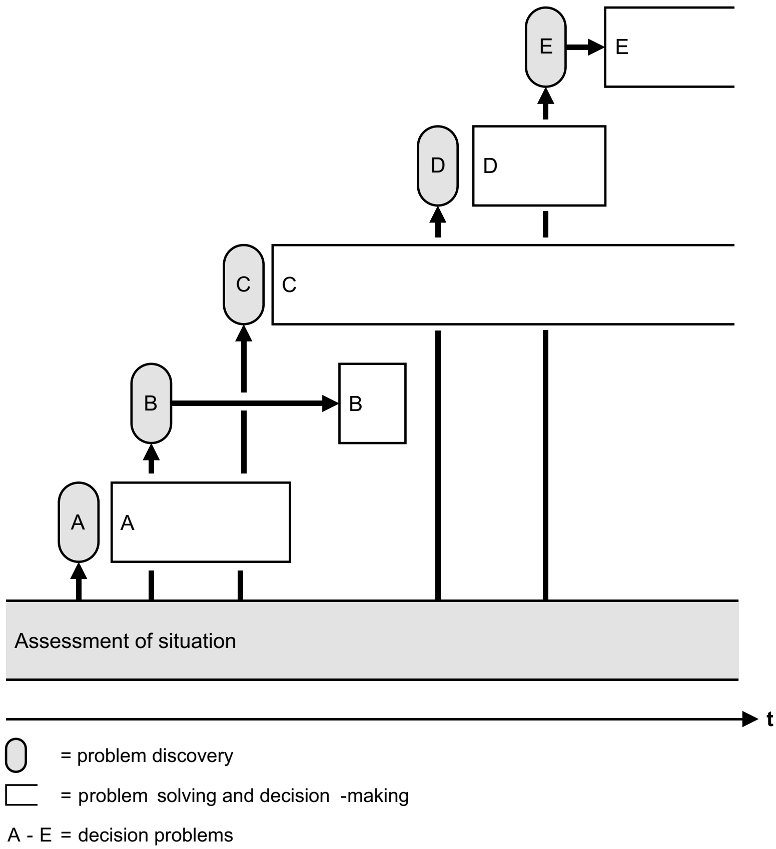

Fig. 3.1 Discovery of decision problems as part of the situation assessment (Grünig 2023, p. 40)

usually not completely consistent. Rather, it is assumed that the perceptions of the company's desired state are partially diffuse and can even include contradictions. It appears to be important to accept this fact and not to eliminate it by simplifying assumptions. Recommendations that are useful for practice can only be developed by accepting reality, and this is the objective of this book. When dimensions of goal systems are proposed below, this is not done to replace a rather vague reality with simple statements. The reason is to create a basis to communicate more precisely about the complex phenomenon.

Figure 3.2 shows the most important dimensions of goal systems and their possibilities (see Grünig et al. 2022, p. 130; Heinen 1976, pp. 107 ff.; Macharzina and Wolf 2015, p. 202; Stelling 2005, pp. 7 f.; Thommen 2002, pp. 114 f.; Ulrich and Fluri 1995, pp. 97 ff.; Wöhe 1996, pp. 124 ff.). For further, more differentiated considerations, the reader can refer to Heinen (see 1976, pp. 89 ff.) and Stelling (2005, pp. 8 f.).

The three criteria can be used simultaneously to structure a goal system. Figure 3.3 presents an example of a goal system with the primary goal of maximizing return on equity and several secondary goals. Apart from above-average product

Dimensions	Possibilities			
(1) Importance	Primary goals		Secondary goals	
(2) Content	Market position goals	Perfor-mance goals	Financial goals	Society-related goals
(3) Required degree of goal achievement	Optimal goals		Satisfying goals	

Fig. 3.2 Dimensions of goal systems and their possibilities

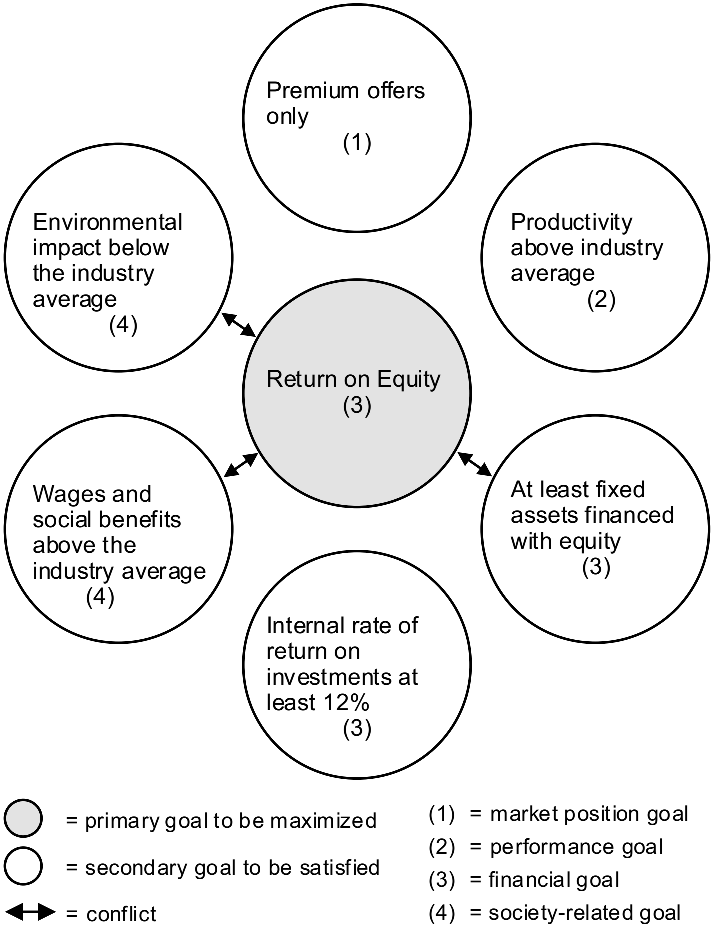

Fig. 3.3 Example of a goal system

quality, which leads to above-average profitability according to empirical research (see Buzzell and Gale 1987, pp. 89 ff.), the additional goals all have a negative effect on return on equity. At the same time, these goals reduce risks and improve societal acceptance.

Empirical research on goals investigates the goals that are actually pursued by the companies. Inset 3.1 presents the results of such studies.

Inset 3.1 Goals Pursued in Practice

This inset is based on Grünig et al. (2022, pp. 124 ff.).

A synthesis of numerous studies shows which goals companies consider to be the most important (see Raffée and Fritz 1992; Macharzina and Wolf 2015, p. 234; Welge and Al-Laham 2008, p. 205; Becker 2013, p. 18; Deloitte 2019, p. 13):

- Cost savings
- Customer satisfaction
- Environmental protection
- Long-term profit
- Maintaining competitiveness
- Market share
- Productivity increase
- Quality of the offer
- Return on assets
- Return on equity
- Securing the company's existence
- Social responsibility
- Turnover growth

The studies can be summarized as follows (see Welge and Al-Laham 2008, p. 204):

- Financial goals dominate.
- Society-related goals, such as social responsibility and environmental protection, have become more important over the decades. They have moved up to the top level of the goal hierarchy.

3.3 Problem-Finding Systems

To discover decision problems systematically and at an early stage, companies develop and use problem-finding or monitoring systems. Problem-finding systems are (see Kühn and Walliser 1978, pp. 227 ff.):

- Subsystems of the company information system, which
- Procure, process, store, and provide information
- To serve, among other tasks or exclusively, to discover decision problems

Every company possesses a legally required tool—financial accounting—that can serve as a problem-finding system in addition to reporting and documentation purposes. However, it is a problem-finding system that reacts late and often too late to set the necessary problem-solving process in motion. For this reason, in addition to the required financial accounting, most companies also set up and use systems that serve exclusively for early problem discovery.

There are two categories of problem-finding systems (see Kühn and Walliser 1978, pp. 229 ff.):

- Problem-finding systems of accounting, which use goal indicators. These indicators can be both general goals, such as return on capital, and differentiated goals, such as the turnover of product groups, countries, or product groups per country.
- Early warning systems, based on cause indicators. Cause indicators are variables that have a cause-effect relationship to a goal indicator and therefore show problems earlier. To illustrate this, Inset 3.2 presents the early warning indicators of Parfitt and Collins (1968, pp. 131 ff.) for monitoring the market position of consumer goods.

Inset 3.2 Early warning system of Parfitt and Collins

Market share is an important measure for planning and monitoring the market position of consumer goods. Parfitt and Collins (1968, pp. 131 ff.) developed an early-warning system that can predict changes in market share and react quickly in case of signs of a decrease. It is based on four quantitative indicators of a period, e.g., a quarter:

- $$\text{Quantitative market share of product a} = \frac{\text{Sales volume of product a}}{\text{Sales volume of all products in product category A}}$$
- $$\text{Penetration of product a} = \frac{\text{Number of consumers who have purchased product a at least once}}{\text{Number of consumers for products in product category A}}$$
- $$\text{Repurchase rate of product a} = \frac{\text{Ø Number of purchases made by consumers of product a}}{\text{Ø Number of purchases made of all consumers in product category A}}$$
- $$\text{Purchase intensity of product a} = \frac{\text{Quantity of product a per purchase}}{\text{Quantity of product category A per purchase}}$$

(continued)

Inset 2.1 (continued)

The four indicators are in an arithmetic relationship to each other:

$$\text{Quantitative market share of product a} = \frac{\text{Penetration of a} \bullet \text{Repurchase rate of a} \bullet \text{Purchase intensity of a}}{100}$$

The functioning of the early-warning system is now illustrated with the help of an example. The following figure shows the current quantitative market share of Inova Inc.'s product group "a" compared to the quantitative target market share for four quarters. In addition to this market share comparison, the table shows the values for Parfitt and Collins' three problem indicators. Contrary to the target–current market share comparison, which raises no cause for concern throughout all four quarters, the repurchase rate has fallen from the second quarter on, indicating a problem of decreasing customer satisfaction. This problem has not yet had a negative effect on the turnover, because an advertising campaign in quarters 2, 3, and 4 has attracted new buyers and led to increased penetration. However, if—once the advertising campaign is over—penetration falls to the original level of 40%, and repurchase rate and purchase intensity remain the same at 30% and 0.63 respectively, market share in the next quarter will drop to 7.56%.

Parfitt and Collins' indicators thus allow problems in market position to be discovered before market share is affected and the problem becomes acute (see Grünig 2002, pp. 34 f.; Kühn and Walliser 1978, pp. 237 ff.).

Indicators \ Quarter	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
(1) Current penetration	40%	44%	49%	52%
(2) Current repurchase rate	39%	35%	32%	30%
(3) Current purchase intensity	0.63	0.64	0.63	0.63
(4a) Current quantitative market share	9.83%	9.86%	9.88%	9.83%
(4b) Target quantitative market share	10%	10%	10%	10%

Parfitt and Collins indicators for Inova Inc.'s product group a (adapted from Grünig 2002, p. 36; Kühn and Walliser 1978, p. 239)

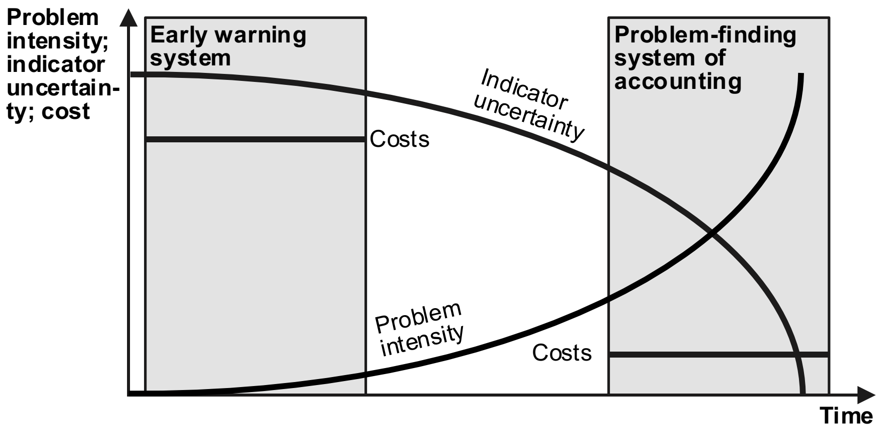

Fig. 3.4 The advantages and disadvantages of the two types of problem-finding systems (adapted from Kühn and Walliser 1978, p. 231)

Figure 3.4 shows the advantages and disadvantages of problem-finding systems based on accounting and early-warning systems:

- Early-warning systems react early and show problems before they have escalated too far. This helps the actor to gain valuable time. In contrast, problem-finding systems based on accounting respond late. Accordingly, the actor is often only confronted with the problem when it is already too late for effective measures.
- With the use of early-warning systems, there is the risk of a false alarm. Such a false alarm causes, in any case, an unnecessary analysis effort. If it is not noticed that the indicated problem does not exist, the false alarm can even lead to unnecessary and therefore ineffective measures. With problem-finding systems based on accounting, this risk is practically nonexistent. When they react, there is a high probability that a decision problem exists.
- Early-warning systems usually generate substantial costs to obtain information, whereas accounting-based problem-finding systems can rely considerably on existing information.

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4 Rational Problem-Solving

4.1 Approaches to Solve Decision Problems

As shown in Sect. 2.1, a decision problem arises when a difference between the current and the target situation can be reduced or even eliminated by various possible solution options. The solution option to be realized can be chosen in very different ways:

- Adoption of an unquestioned expert solution.
- Intuitive choice of a solution option.
- Selection of a solution option that has proven itself based on experience or.
- Determination of a solution option through a rational problem-solving process.

As Fig. 4.1 shows, the four possible approaches to solving decision problems, from the authors' point of view, result in different solution qualities. A rational problem-solving process generally leads to a better decision than relying purely on intuition or experience. The adoption of a standard solution from an expert is considered particularly critical. Expert solutions can be a good starting point for developing a solution to a problem. However, it is important that they are adapted to the specific situation of the company.

The preference for a rational problem-solving process does not mean that the authors consider the intuition and experience of managers to be unessential. Even in a rational problem-solving process, incomplete information and uncertainties about the effects of possible courses of action force the actors to fall back on their experience and intuition. If—as is often the case in practice—decisions must be made under time pressure, the need to bridge missing information with intuition and experience increases. Intuition and experience are, therefore,

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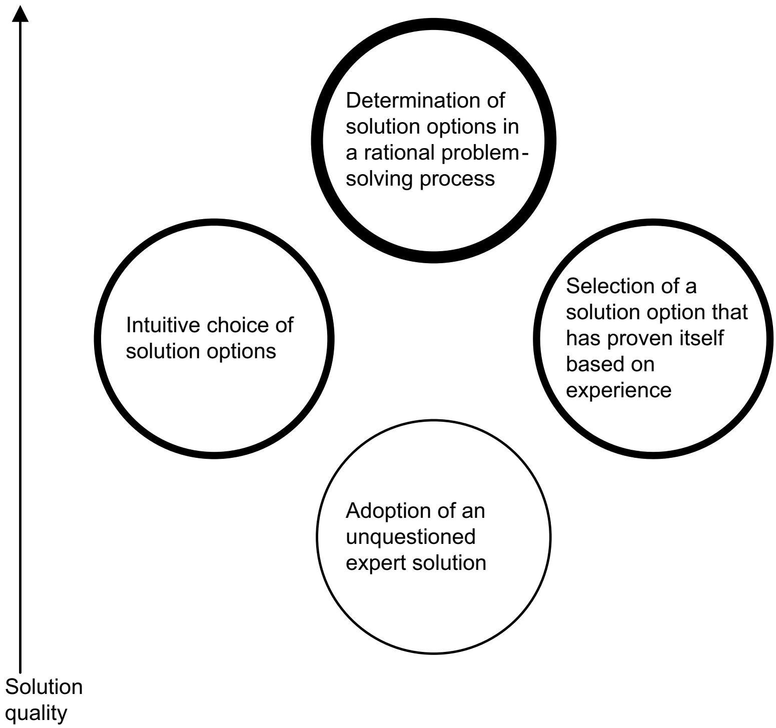


Fig. 4.1 The qualities of the different approaches to solving decision problems

important additions to a rational problem-solving process (see Robbins et al., 2011, pp. 92 f.).

Rational problem-solving is often based on a problem-solving procedure. Chapter 5 shows what is meant by a problem-solving procedure and what types of procedures exist.

4.2 Distinction Between Formal and Substantial Rationality

The term "rational" is often used in connection with problem-solving processes; however, it lacks a precise description. To get a clearer idea of what is meant by rational problem-solving, a distinction must be made between formal rationality and substantive or content-related rationality (see Bamberg and Coenenberg, 2002, pp. 3 f.; Brauchlin, 1990, pp. 344 f.; Pfohl and Braun, 1981, pp. 129 f.):

- We speak of formal rationality when the goals pursued are not questioned for their rationality. The rationality requirements, therefore, only refer to the problem-solving process.

- Substantive or content-related rationality, on the other hand, presupposes that the goals are rational because they constitute the only acceptable, “right” goals. The required rationality therefore refers not only to the problem-solving process but also to the goals pursued. They become the only “right” goals, alongside which all other goals appear “wrong” (see e.g., Pfohl and Braun, 1981, p. 129).

Most researchers assume that the choice of the overriding goals or values that form the basis for discovering and solving decision problems is subjective. The overriding goals or values cannot, from a scientific point of view, be qualified as objectively right or wrong. Most researchers, therefore, accept that the pursued goals in a decision problem are subjective. “You live for values, you die for values, if necessary. But you cannot prove values” (Sombart, 1967, p. 83, translated by the authors). Since there are no “right” goals, only formal rationality represents a reasonable requirement for problem-solving processes.

The fact that there are no scientifically provable “right” goals does not mean that companies are entirely free in defining their goals. They bear responsibility for the goals they pursue. They must ensure that these goals comply with ethical or moral standards in the sense of corporate social responsibility (see Bowen, 1953; Carroll, 1991, pp. 39 ff., Crane et al., 2008).

4.3 Requirements for a Formal-Rational Problem-Solving Process

As Eisenführ and Weber state, later success or failure is no yardstick. A distinction must clearly be made between a formal-rational problem-solving process and a successful decision. A formal-rational approach should produce more successful decisions. However, to assume that with formal rationality, one could overcome the many uncertainties inherent in a decision and guarantee success would represent a false understanding of rationality. Eisenführ and Weber clarify the difference between successful and rational decisions with the following simple example: if, after careful analysis, you invest in shares and your investment later takes a nosedive, the decision does not later become less rational. If a student puts down his last 100 euros on number 17 in a roulette game and wins, the decision is not more rational because of this success than it was before (Eisenführ and Weber 2003, p. 4).

Rationality does not refer to the success of the chosen and realized option but to the problem-solving process. According to the authors, a problem-solving process is formally rational if it meets the following requirements:

1. Continuously goal-oriented
2. Based on available and obtainable information
3. Systematic process
4. Complying with the rules of formal logic
5. Comprehensible and non-influencing statements

The goal-orientation requirement for formal-rational decisions—requirement (1)—affects all essential steps of the problem-solving process. Even problem discovery is based on unachieved goals or goals that could be better achieved. Problem analysis seeks explanations for the nonachievement of goals. Consequently, only measures and means that promise an improvement in the fulfillment of the goals should be discussed as solution options. Finally, the evaluation of options is based on decision criteria that have been derived from the pursued goals (see Eisenhardt and Zbaracki 1992, p. 18; Kühn 1969, pp. 6 ff.; Pinker 2021, pp. 52 f.).

The requirement for a decision process to be based on available and obtainable information—requirement (2)—may seem obvious. However, formal rationality does not require information to be complete. Cost-benefit considerations are made when procuring information. It, therefore, depends on the importance of the problem to be solved and the time pressure as to which information procurement effort is justified. However, it would simply be unrealistic to demand a complete and reliable information base, including future developments. Formal rationality strives only for the most objective and complete information possible. As already mentioned in Sect. 4.1, the missing information must be compensated for by intuition and experience (see Kühn 1969, pp. 6 ff.).

The requirement for a systematic process—requirement (3)—is intended to ensure that outsiders can understand the way of problem-solving. However, this comprehensibility does not mean that every outsider must agree with the chosen solution. An outsider may pursue different goals, interpret unsure information differently, or have information at his disposal that is different from that of the actor. Accordingly, he also decides differently (see Kühn, 1969, pp. 6 ff.).

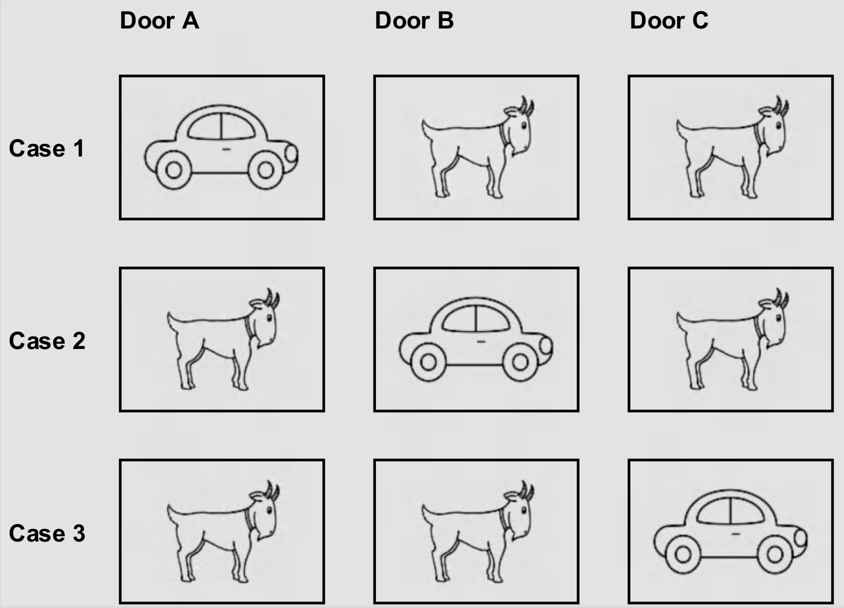
Compliance with the rules of formal logic (see Pinker, 2021, pp. 90 ff.)—requirement (4)—is a matter of course in a rational problem-solving process. It affects all steps of the problem-solving process, especially the evaluation of the solution options. As shown in Inset 4.1, adhering to the rules of decision logic is sometimes challenging and requires thoroughness in the problem-solving process. In practice, more banal violations of formal logic can also be observed. For example, sunk costs may be considered as consequences of options, even though they cannot logically be so.

Inset 4.1 Compliance with the Rules of Formal Logic as a Challenge
As Pinker (2021, pp. 28 ff.) explains, following the rules of formal logic is not a matter of course. This is because it often lacks the necessary thoroughness. Pinker illustrates this with an example in which even renowned mathematicians made the wrong decision. The example in question is the game show "Let's Make a Deal," which was very popular in the USA for many years of the last century (see Pinker, 2021, p. 32).

(continued)

Inset 4.1 (continued)

A player stands in front of three doors. Behind one door is a sleek new car. Behind the other two are goats. The player picks a door (see Pinker, 2021, p. 32). As the following illustration shows, the probability of winning is 1/3 for each door.



Visualization of the game (based on Pinker, 2021, p. 35)

After the player picks a door, the game host opens one of the two other doors, revealing a goat. The host then asks the player whether he or she would like to stick with the original choice or switch to the other unopened door (Pinker, 2021, pp. 32 ff.).

As Pinker (2021, pp. 32 ff.) explains, almost all players stick with their first choice and do not switch doors. However, this is a mistake because opening a door with a goat changes the game situation.

If the player sticks with the first choice, he still has a 1/3 probability of winning. This means that the probability of winning by switching the door is 2/3. The probability that the car is behind the unselected, unopened door doubles because the game host opened a door with a goat behind it. The open door and the unselected, unopened door thus form together a unit in the decision to switch doors.

Comprehensible and non-influencing statements—requirement (5)—make goal orientation easier. The purpose of this requirement is to avoid so-called framing effects, which consciously influence or manipulate the actor. Kahneman and Tversky (1982, pp. 136 ff.) empirically proved that an actor's decision can be influenced by framing. Inset 4.2 shows an example of such a framing effect.

Inset 4.2 Influencing the Decision by Framing

The example of von Nitzsch (2002, pp. 113 ff.) compares two decision-making situations:

- "Situation A: You receive EUR 1000 in an envelope and can choose whether to receive a further EUR 500 or participate in a game in which you have a 50% probability of receiving nothing or additional EUR 1000.
- Situation B: You receive EUR 2000 in an envelope and can choose whether to return EUR 500 or participate in a game in which you have a 50% probability of returning additional EUR 1000 or nothing" (von Nitzsch, 2002, p. 113).

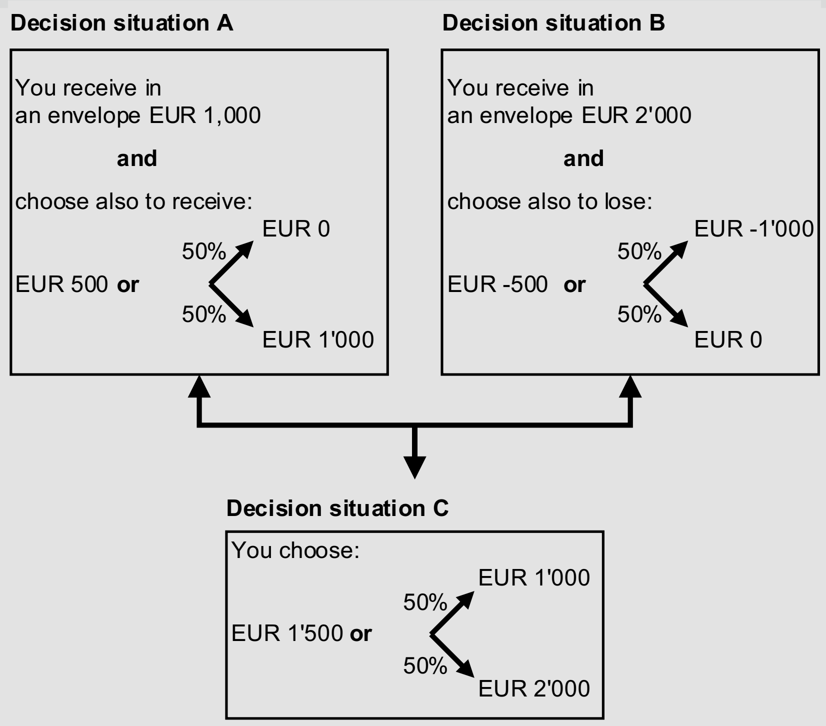
As the following figure shows, the two decision situations are indeed identical: it is the decision as to whether one prefers a sure amount of EUR 1500 to a game in which one has a 50% probability of gaining EUR 1000 or EUR 2000 (von Nitzsch, 2002, p. 113).

As empirical studies by Kahneman and Tverski (1982, pp. 136 ff.) show, most participants make different decisions in decision situations A and B. Participants in situation A behave in a risk-averse manner and choose the sure amount. In situation B, they are risk-seeking and choose the game. A framing is therefore created by how the decision situation is presented.

Von Nitzsch explains this different behavior by the fact that decision situations A and B suggest a two-step game situation. The sure amounts in the first step create the reference point for the second step. The higher sure amount in the first step of the game in decision situation B entices the actor to behave more riskily than the lower sure amount in decision situation A.

(continued)

Inset 4.2 (continued)



Three illustrations of the same decision problem (based on von Nitzsch, 2002, p. 113)

A formal-rational decision is only possible if the actor can make an uninfluenced decision. It is therefore important that the decision problem is presented to him in the form C.

4.4 The Limits of Formal Rationality

Even if the actor endeavors to meet the requirements of formal rationality described in Sect. 4.3 in the best possible way, their problem solution will most likely not be totally formally rational. Analysis, solution development, and decision-making are almost always subject to Simon's (1966, p. 19) principle of bounded rationality. It states that a 100% formally rational decision is impossible and that the actor should, therefore, strive for a satisfactory solution rather than an optimal one.

There are several reasons as to why there are limits to formal rationality in most decision problems:

- As already mentioned, the actor practically never has complete, up-to-date, and precise information.
- Most decision problems are ill-structured according to Simon and Newell (1958, pp. 4 ff.). This means that there is no problem-solving procedure that can guarantee the optimal solution (see Sect. 5.4).
- However, the most important reason probably lies in the limits of human judgment. Actors are always "biased" and therefore unable to analyze and make decisions in an absolutely goal-oriented manner. As Bazerman and Moore (2009, pp. 40 f.) put it, empirical research has identified a wide variety of such "biases."

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5 Problem-Solving Procedures

5.1 Notion of Problem-Solving Procedure

A problem-solving procedure

- Is defined as a system of intersubjectively comprehensible rules for obtaining and processing information
- That can be used to resolve a certain type of decision problem (see Grünig 1990, pp. 69 f.; Gygi 1982, p. 20; Klein 1971, p. 31; Kühn 1978, p. 52 and p. 139; Little 1970, pp. B-469 f.; Streim 1975, pp. 145 f.)

To understand this definition better, the following remarks seem appropriate:

- To speak of a problem-solving procedure, the system of rules should address all essential subtasks involved in solving a decision problem. These are: problem analysis, the development of options, the evaluation of the options, and the decision. Rule systems that only support the actor in overcoming one of these tasks are not referred to as problem-solving procedures. Such rule systems exist, for example, to develop options or to determine the overall consequences. The rule systems mentioned first are often called creativity techniques, whereas the second rule systems are known as decision maxims.
- Very different types of rule systems exist. This is already reflected in their external form. The spectrum ranges from verbal rules about figures representing the procedure to mathematical algorithms. However, the differences in the content are more important.
- The rules refer primarily to the processing of information. They usually only contain vague indications about what information is needed and generally make no recommendations as to how to procure the information. This is understandable, as the ability to procure decision-relevant information will be shaped by the specific decision situation.

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5.2 Dimensions of Problem-Solving Procedures and Their Characteristics

Management science's aim to support the decision-maker in his task has led to many different propositions for procedures. They can be subdivided into categories according to different criteria. From a practical point of view, three criteria seem important:

- The scope of different problems to which the procedures can be applied
- The formal application conditions for the use of the procedures and
- The quality of the solutions produced by the procedure

According to the criterion of the scope of the underlying problems, a distinction can be made between general and specific problem-solving procedures. Whereas general problem-solving procedures claim to be helpful in tackling any problem, specific problem-solving procedures are designed to tackle problems that are narrowly defined. Examples of the latter are the development of a corporate strategy or the determination of the optimal quantity of stock of a product group.

The use of a problem-solving procedure may be subject to restrictive formal application conditions. Some of these are explicitly named. Others, however, are partially merely implicit and manifest themselves to the actor as difficulties only during the application of the procedure. The most frequently encountered formal application condition is that the procedure includes only quantitative decision variables and quantitative decision criteria and thus excludes qualitative aspects of the problem. Due to the formal application conditions, a distinction is made between procedures with restrictive formal application conditions and procedures without essential formal application conditions. This distinction is deliberately imprecise at this point; a more differentiated view of the most important formal application conditions of problem-solving procedures is given in Inset 5.1.

Depending on the quality of the solutions produced, a distinction can be made between procedures with an optimal solution and those with only a satisfactory solution.

Figure 5.1 summarizes these explanations.

5.3 Types of Problem-Solving Procedures

In the previous subsection, three dimensions were introduced to distinguish problem-solving procedure categories: the scope of the problem, the formal application conditions, and the quality of the produced solutions. There is a connection between the two dimensions "formal application conditions" and "quality of produced solutions": restrictive formal application conditions make it possible to determine the optimal solution. Equally, the abandonment of narrow formal application conditions means that there is no guaranteed solution and that the best-found solution will only

Dimensions	**Possibilities**	
(1) Scope of the underlying problem	General problem-solving procedures to tackle any problem	Specific problem-solving procedures to tackle specific problems
2) Formal application conditions	Problem-solving procedures with restrictive formal application conditions	Problem-solving procedures without essential formal application conditions
3) Quality of the produced solution	Problem-solving procedures that aim for an optimal solution	Problem-solving procedures that aim for a satisfactory solution

Fig. 5.1 Dimensions of problem-solving procedures and their possibilities

Scope of the underlying problems / Formal application conditions and solution quality	**General use to tackle any problem**	**Use only to tackle specific problems**
No essential formal application conditions; Satisfactory solution is aimed for	General heuristic problem-solving procedure	Specific heuristic problem-solving procedure
Restrictive formal application conditions; Optimal solution is aimed for	General analytic problem-solving procedure	Specific analytic problem-solving procedure

Fig. 5.2 Types of problem-solving procedures

exceptionally be the optimal solution. Therefore, in the end, the two criteria represent only two different ways of considering the same phenomenon.

As two categories of procedures can be distinguished based on the content scope and on the application conditions or solution quality, we have to deal with a total of four types of procedures. Figure 5.2 shows these four types of problem-solving procedures.

More sophisticated approaches to the formation of categories of problem-solving procedures exist in literature (e.g., Fischer 1981, p. 297; Streim 1975, p. 151). However, it is enough to distinguish the four types for our purposes: it delimits the general heuristic problem-solving procedure that interests us from the other three types of procedures.

5.4 Comparison of Heuristic and Analytic Problem-Solving Procedures

Before comparing these two types of problem-solving procedures, the word "heuristic," uncommon in colloquial language, must first be clarified:

- The word "heuristic" has its origin in an ancient Greek verb that can be translated as "to seek" or "to find." Accordingly, the adjective "heuristic" can be understood as "suitable for finding" (Klein 1971, p. 35).
- "A heuristic […] is a rule of thumb, strategy, trick, simplification, or any other kind of device which drastically limits search for solutions in large problem spaces. Heuristics do not guarantee optimal solutions; in fact, they do not guarantee any solution at all; all that can be said for a useful heuristic is that it offers solutions which are good enough most of the time" (Feigenbaum and Feldman 1963, p. 6). A heuristic is thus understood as a rule of thinking that helps reduce the effort or cost of finding solutions to complex problems.

The essential advantages of heuristic problem-solving procedures, in comparison to analytic procedures, lie in the almost total absence of formal application conditions and in their relatively low application costs. The disadvantages associated with heuristic problem-solving procedures are the absence of any guarantee of a solution and, if a solution can be found, the lack of guarantee that it is the optimal solution. Figure 5.3 shows the difference between heuristic and analytic problem-solving procedures.

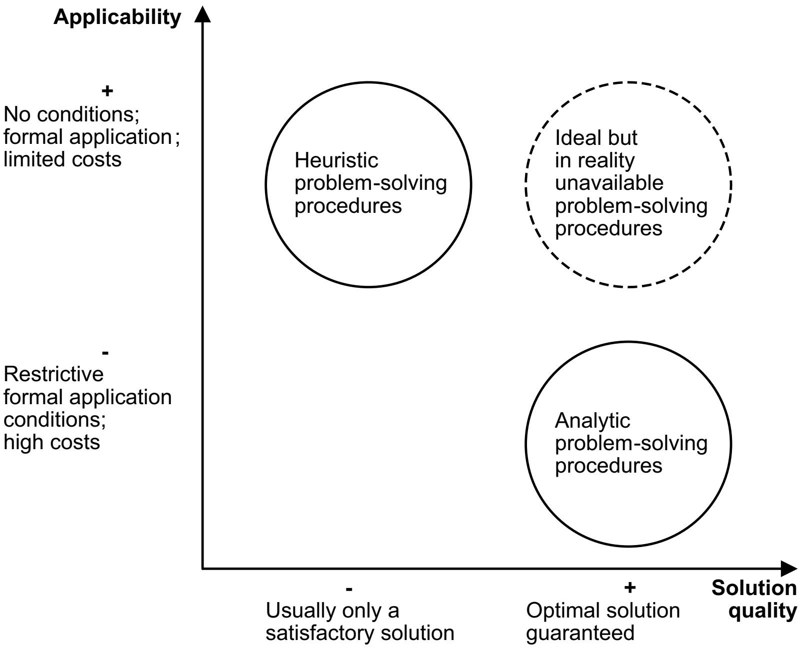


Fig. 5.3 Comparison of heuristic and analytical problem-solving procedures

As previously mentioned, analytic problem-solving procedures guarantee the optimal solution by restrictive formal application conditions. Inset 5.1 shows the application conditions that must be met when using analytic procedures. Since the actor will have to resort to a heuristic problem-solving procedure if one of the application conditions is not fulfilled, the inset also allows the heuristic problem-solving procedure to be more precisely positioned.

Inset 5.1 Well-Structured Problem as a Condition for Using an Analytic Problem-Solving Procedure

To apply an analytic problem-solving procedure, the underlying problem must be "well-structured" in the terms of Simon and Newell (1958, pp. 4 ff.). To qualify as well-structured, the problem must satisfy three specific conditions.

The first condition for the use of an analytic procedure is that the problem description contains only quantitative aspects or is reduced to quantitative aspects.

The second condition is that clear rules must specify whether a developed solution is acceptable or not. When such rules exist, a problem is considered well-defined according to Minsky. If no such rules exist, it is an ill-defined problem (see Klein 1971, p. 32; Minsky 1961, pp. 8 ff.).

Rules of this kind exist, for instance, for the game of chess. The rules make it unequivocally clear when a king is in checkmate and the opposing player has therefore won. The question of who applies the rules is irrelevant because they leave no room for subjective judgments.

However, a well-defined problem can still be spoken of when the rule system for the selection of acceptable solutions includes subjective judgments. This is the case, for example, when the actor's attitude to risk must be considered when determining the optimal solution. In this case, the procedure remains clear and independent of the person. However, the use of the procedure is always based on subjective attitudes to risk. This means that the same solution is not optimal for every actor.

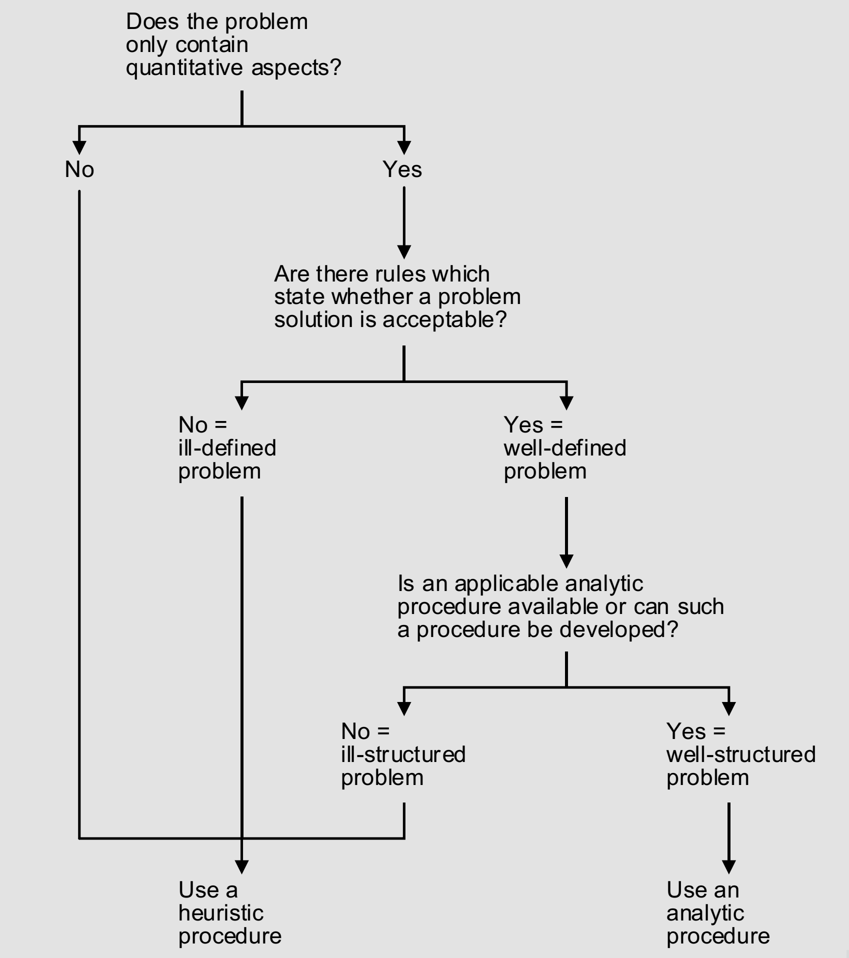
The third condition is that it must be possible to develop an analytic procedure, which the actor can use to find the optimal solution (see Klein 1971, pp. 32 ff.). To this day, this has not succeeded for chess, for example: there is no procedure that guarantees the winning of a game. The powerful chess programs that exist today are based on heuristic rules.

If there is an analytic procedure that can be applied, or if such a procedure can be developed, then we may speak of a well-structured problem according to Simon and Newell. Otherwise, it is an ill-structured problem (see Klein 1971, p. 32; Simon and Newell 1958, pp. 4 ff.).

These statements are summarized in the following figure.

(continued)

Inset 5.1 (continued)



Conditions for using an analytical problem-solving procedure

5.5 Examples of the Different Types of Problem-Solving Procedures

5.5.1 Introduction

To give the reader a more concrete idea of the different types of problem-solving procedures, three concrete procedures are now presented. These are then used to clarify the differences between the types of procedures.

Since Part II is dedicated to the description of a general heuristic problem-solving procedure, an example from this category of procedure is not necessary for the moment. Chapter 6 gives an overview of the proposed general heuristic problem-solving procedure.

5.5.2 Example of a Specific Heuristic Problem-Solving Procedure

The strategy planning process proposed by Grünig, Kühn, and Morschett (see 2022, pp. 33 ff.) is an example of a specific heuristic problem-solving procedure. As Fig. 5.4 shows, the complex task of analysis and planning is divided into six steps.

The occurrence of loops at any time is typical of a heuristic process. The loop in Fig. 5.4 only represents a particularly important example. The possibility of heuristic loops in the whole process signifies that all the results of the analysis and planning steps should be considered as provisional until the work is completed.

As Fig. 5.4 shows, Steps 2 and 4, as well as Steps 3 and 5, are parallel. This indicates the strong interdependencies that exist between the company level and the business level in both analysis and planning. Accordingly, it is possible that:

- Analysis and planning are first executed at the corporate level and then at the business level.
- The analysis and planning tasks are first carried out at the business level and afterwards at the corporate level.
- The two activities take place at both levels in parallel.

5.5.3 Example of a General Analytic Problem-Solving Procedure

A good example of a general analytic problem-solving procedure is linear programming. The technique is illustrated with the help of a simple example. The example of Bertsimas and Freund (2004, pp. 328 ff.) contains a problem with only two decision variables. This allows the finding of the solution to be graphically presented. If more than two decision variables exist—and this is the norm in practice—the same approach can be used with the help of an algorithm, similar to the graphical approach in the example.

The example assumes that a company produces and sells two products (I and II), each passing through three cost centers (A, B, and C). The two products make different use of the capacities available in the cost centers. Each product has a predetermined price and a maximum sales quantity.

Based on the initial data shown in Fig. 5.5, it can be determined which product types should be produced and sold in which quantities so that the company maximizes its profit (see Bertsimas and Freund 2004, p. 328).

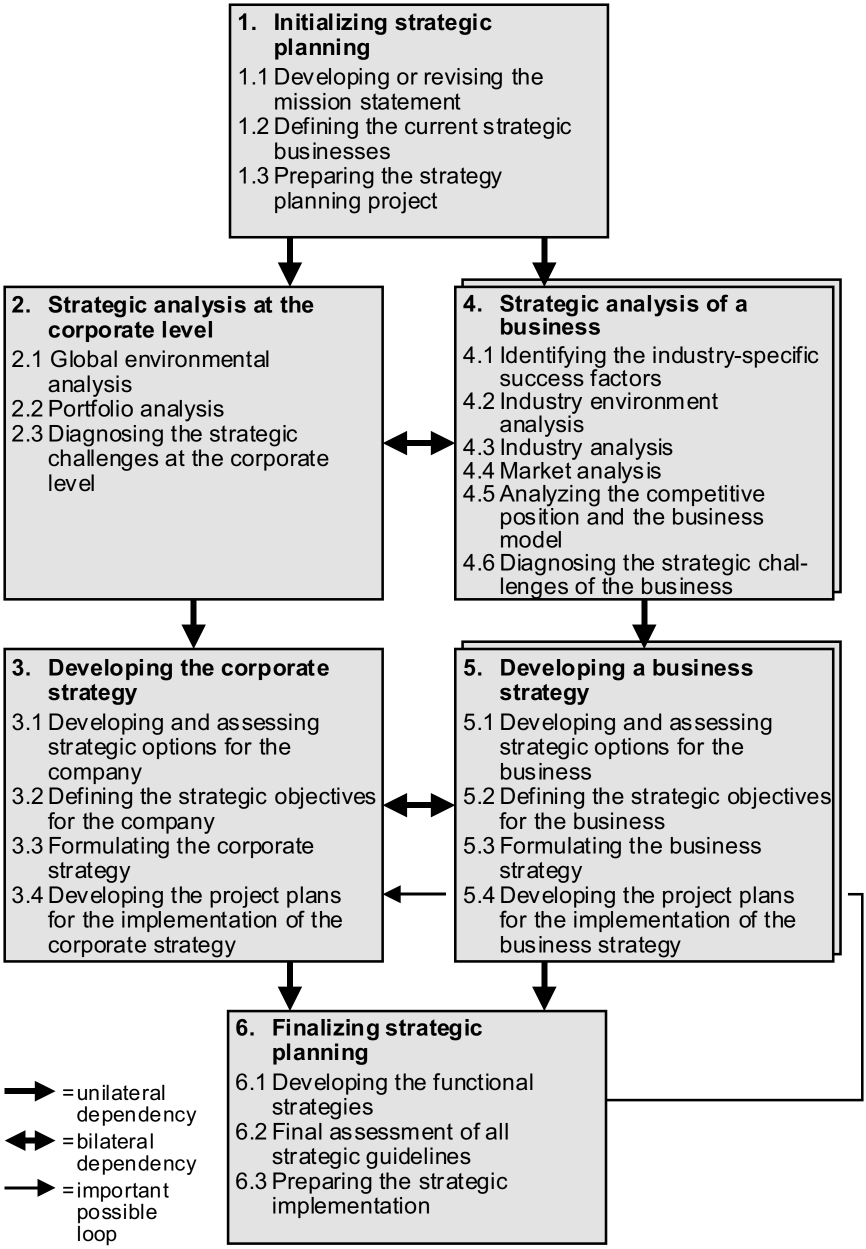


Fig. 5.4 Strategy planning process (Grünig et al. 2022, p. 35)

Product information

Product	Selling price	Variable costs	Maximum sales quantity
I	USD 270	USD 140	15 units/day
II	USD 300	USD 200	16 units/day

Cost center information

Cost center	Capacity	Product I processing time	Product II processing time
A	27 hours/day	1.5 hour/unit	1 hour/unit
B	21 hours/day	1 hour/unit	1 hour/unit
C	9 hours/day	0.3 hour/unit	0.5 hour/unit

Fig. 5.5 Raw data to determine the optimal sales and production program (adapted from Bertsimas and Freund 2004, p. 328)

The information from Fig. 5.5 is incorporated step-by-step into Fig. 5.6. Its horizontal axis indicates the number of units for product I, and its vertical axis indicates the number of units for product II:

- First, the two restrictions on sales and the three production restrictions are plotted.
- Then, the option space is determined.
- After this, the gradient of the goal function is determined. Since a unit of product I can generate 30% more contribution margin than a unit of product II, 30% more pieces of product II are needed to realize the same total contribution margin. The goal functions, each one representing the same total contribution margin, are therefore steeper than 45°.
- The line representing the goal function is now moved parallel and toward the right upwards as far as possible without leaving the option space.
- As can be seen in the figure, the optimum sales and production program is 12 units of product I and 9 units of product II.

5.5.4 Example of a Specific Analytic Problem-Solving Procedure

An example of a specific analytic problem-solving procedure is Harris and Wilson's model for determining the optimal order quantity of a product. As shown in Fig. 5.7, the model assumes both a constant demand for the good and the delivery of all the quantities ordered without any time delay. Furthermore, it is assumed that the order quantity has no influence on the procurement price. It is also assumed that enough

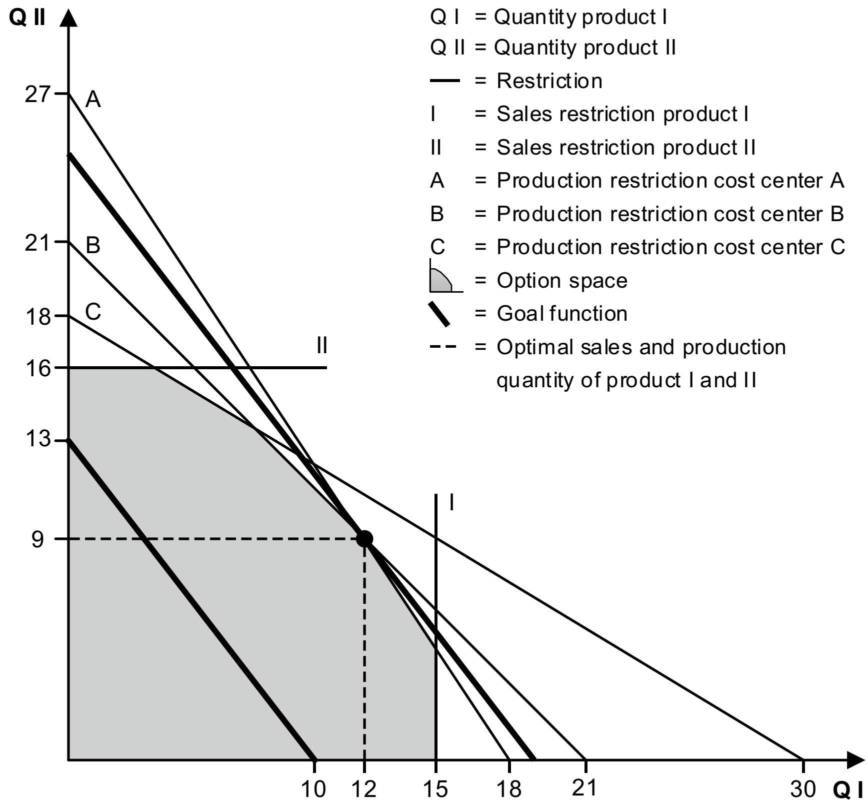


Fig. 5.6 Graphical determination of the optimal sales and production program

storage space exists for any order quantity, so that there are no costs for third-party storage. Based on all these assumptions, the model minimizes the costs that depend on order quantity (see Simchi-Levi et al. 2009, pp. 33 ff.).

Regarding costs dependent on order quantity, there are, first, the expenses accrued with each order process. These increase when smaller quantities are ordered. Second, the storage costs, which increase with larger order quantities, are included in the optimization process. Figure 5.8 shows the two cost components, the total costs, and the optimal order quantity calculated with the Harris and Wilson model (see Simchi-Levi et al. 2009, p. 34).

The determination of the optimal order quantity is illustrated with the help of an example. The example is based on the following data (see Simchi-Levi et al. 2009, p. 35):

- Annual demand = 50,000 units.
- Storage costs = 0.25 Swiss francs per unit per year.
- Costs per order = 20 Swiss francs.

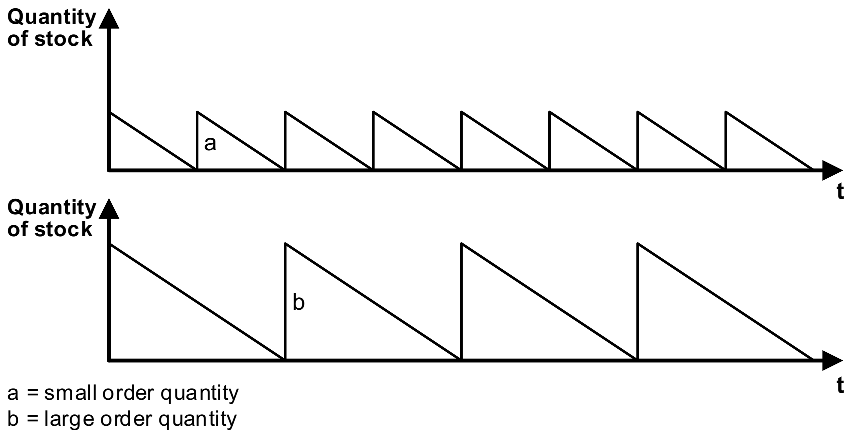


Fig. 5.7 Harris and Wilson's saw-tooth model of stock movements

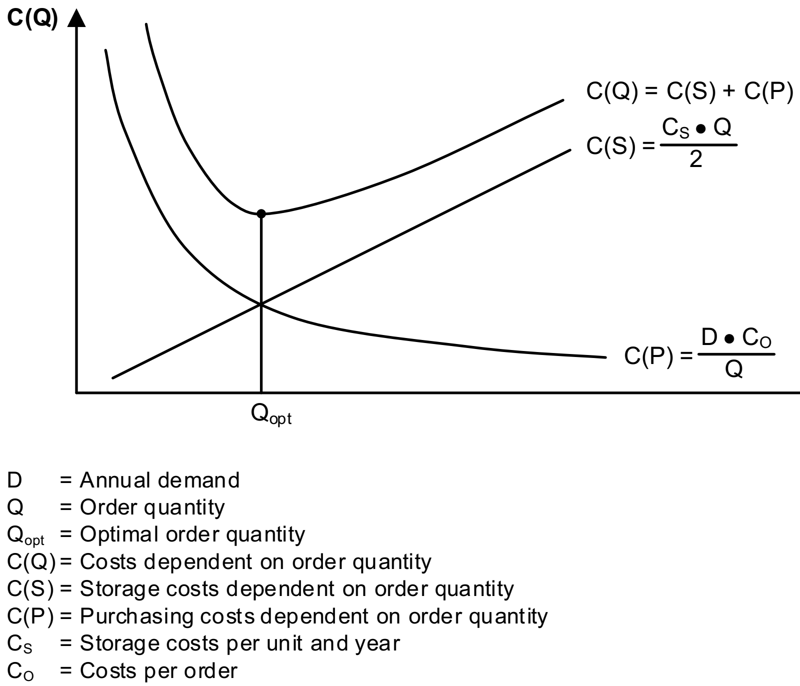


Fig. 5.8 Cost function of the Harris-Wilson model (adapted from Simchi-Levi et al. 2009, p. 34)

The cost function that is dependent on the order quantity can be determined based on the three figures:

$$C(Q) = \frac{0.25 \bullet Q}{2} + \frac{50,000 \bullet 20}{Q}$$

The cost function is now derived and set to zero:

$$0.125 - \frac{1,000,000}{Q^2} = 0$$

The optimal order quantity can thus be calculated. It is 2828 units.

5.5.5 Comparison of the Three Examples

The three examples allow an opportunity to clarify the differences between the types of problem-solving procedures once again.

The strategic planning procedure and the Harris-Wilson model for determining the optimal order quantity are suitable to deal with and solve specific decision problems. The name of the problem-solving procedure itself indicates the type of problem. These two procedures can, therefore, be classified as specific problem-solving procedures. In contrast, linear programming is suitable for optimizing problems that are not specified further about the content but are well-structured. It can determine the optimal investment program of a company, solve a transportation problem, or—as in the example—determine the optimal sales and production program. Linear programming, therefore, belongs to the category of general problem-solving procedures.

Both Harris and Wilson's procedure and linear programming have very restrictive formal application conditions. The quantitative information about the initial situation that must be known is very precisely fixed. If one piece of this information is missing, the problem-solving procedure cannot be applied. If one piece of quantitative information is wrong, the procedure will produce a solution that is optimal on paper but not in reality. Both procedures can be classified as analytic procedures. In contrast to these, the strategic planning procedure does not require any precise quantitative information. If the actor has such information, this will increase the quality of the developed strategy, but it is not necessary. In any case, the problem-solving procedure cannot identify the optimal solution. However, the application of the procedure almost certainly results in strategies that the company can use. But no one can say how far away they are from the optimum. Accordingly, the strategic planning procedure belongs to the category of heuristic procedures.

5.6 The Development of Problem-Solving Procedures as a Central Task of Practical-Normative Management Science

Two schools of thought can be distinguished in management science (see Köhler 1978, pp. 186 ff.):

- Empirical-analytical or theoretical management science aims to explain reality. It formulates hypotheses and subjects them to empirical tests. The result of their testing is either a falsification or a confirmation. But a confirmation is only temporary, because the falsification of hypotheses in future empirical tests can never be excluded. The hypotheses are partially developed and tested out of pure cognitive interest. Most of the scientists committed to the empirical-analytical research perspective, however, try to gain insights that are relevant to practice. In the context of decision problems, Gäfgen (1974, pp. 50 ff.) names the empirical-analytical research direction explicative or descriptive decision theory.
- Practical-normative or pragmatic management science aims to support companies with practice-oriented recommendations. In the context of decision problems, Gäfgen (1974, pp. 50 ff.) names the practical-normative research direction prescriptive decision theory.

Both research directions deal intensively with decision problems. This is why Heinen (1969, pp. 207 ff.) speaks of decision-oriented management science:

- Empirical-analytical management science or explicative decision theory examines the decision-making behavior of actors. The extensive work of Kahneman (see, for example, Kahneman 2011; Kahneman et al. 2021; Kahneman and Tversky 1982, pp. 136 ff.; Kahneman and Tversky 2000; Tversky and Kahneman 1992) can be assigned to this direction.
- Practical-normative management science or prescriptive decision theory develops problem-solving procedures. One example is the general heuristic problem-solving procedure proposed in Part II.

As Gäfgen (1974, pp. 50 ff.) shows, explicative and prescriptive decision theory are partly based on the same foundation, decision logic. Inset 5.2 explains the relationship between explicative decision theory, prescriptive decision theory, and decision logic.

Inset 5.2 Explicative Decision Theory, Prescriptive Decision Theory, and Decision Logic by Gäfgen

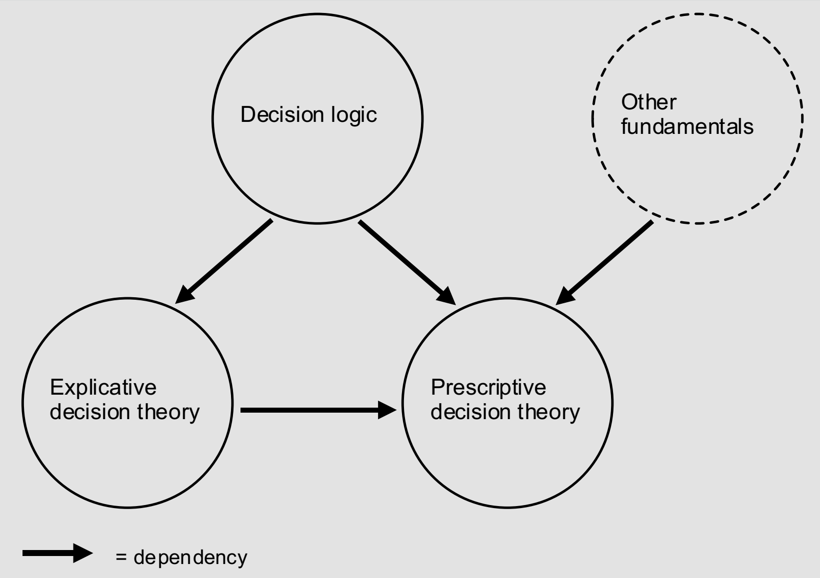
Decision logic develops models of rational choice without considering reality. Such models are logical deductions from postulated assumptions. The results of the deductions are logically true (see Gäfgen 1974, pp. 50 f.). Decision logic forms a subset of the rules of formal logic according to Sect. 4.3.

Decision logic can serve as a basis for empirical research about the extent to which rational decisions are made in practice. In this case, we speak of explicative or descriptive decision theory (see Gäfgen 1974, p. 52).

However, decision logic can also be used as a basis for the development of problem-solving procedures. These are referred to by Gäfgen as prescriptive decision theory (see Gäfgen 1974, p. 52).

Decision logic is undoubtedly an important foundation of prescriptive decision theory. At the same time, however, it must be emphasized that decision logic is not the only foundation. To develop useful problem-solving procedures, additional knowledge about the problem-solving capabilities of actors and practical experience with problem-solving processes are required. Explicative decision theory can also provide insights for developing problem-solving procedures.

The figure shows the dependencies between the different types of decision research.



Different types of decision research and their dependencies

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Part II

A General Heuristic Problem-Solving Procedure

6 Overview of the Problem-Solving Procedure

6.1 Utility of a General Heuristic Problem-Solving Procedure

Before an overview of the proposed procedure is given, the advantages and limitations of a general heuristic problem-solving procedure are first shown. This guarantees that, from the very beginning, readers and potential users of the procedure approach it with realistic expectations.

If the decision problem fulfills all the application conditions for the use of an analytic problem-solving procedure, this procedure should be used. The reason is that, unlike the proposed heuristic approach, it guarantees the optimal solution. However, as has been discussed, a complex decision problem rarely fulfills the application conditions of an analytic problem-solving procedure.

If a specific heuristic problem-solving procedure that matches the decision problem is available, it should be preferred over the proposed general heuristic procedure. This is because the problem-solving steps are well adapted to the problem and allow the actor to make better use of his factual knowledge. However, the availability of a suitable heuristic problem-solving procedure that matches a specific problem is exceptional.

Thus, the actor can normally resort to neither an analytical nor a specific heuristic problem-solving procedure. He is therefore faced with the question of whether he wants to apply the general heuristic problem-solving procedure or not. If he decides not to use the procedure, he will determine an ad hoc procedure. From the authors' point of view, the application of the general heuristic problem-solving procedure has clear advantages over such an ad hoc approach:

- The proposed procedure facilitates consistent alignment of all problem-solving considerations with the primary goals. It thus reduces the probability that a lack of goal orientation will lead to a wrong decision.

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- By separating analysis, development of solution options, and solution assessment, the procedure enables a conscious distinction between factual knowledge and subjective evaluation. It also allows optimal utilization of knowledge regarding the decision-making situation. These two circumstances are generally reflected in higher decision quality.
- The systematic approach associated with the application of the procedure leads to fewer heuristic loops and, therefore, greater decision-making efficiency.

6.2 Sequence of Steps and Subproblems

Figure 6.1 shows the steps of the proposed problem-solving procedure in its basic form. Complex decision problems are usually broken down into several subproblems during problem analysis. Figures 6.2 and 6.3 illustrate the application of the procedure in such cases. They show the course of action for solving two subproblems in parallel and two subproblems one after the other.

The following comments are necessary for all three figures:

- Two subproblems, A and B, can be processed in parallel, as shown in Fig. 6.3. However, since complete independence between the two subproblems occurs only in exceptional cases, the decisions in Step 7 must be coordinated. Figure 6.4 shows a situation where the problem analysis produces a hierarchy of two subproblems. In this situation, the option chosen for the first subproblem forms the basis for solving the second subproblem. Obviously, other more complex cases are also possible. For example, the problem analysis can yield a subproblem A, parallel to two other subproblems, B1 and B2, which are to be solved in succession.
- The figures show only one heuristic loop, which leads back from Step 7 to Step 3. This is considered to be the most important loop. It is inherent in heuristic processes, however, that loops can occur at all stages of the procedure. For example, the decision criteria determined in Step 4 must possibly be revised during the determination of the consequences in Step 6. This loop occurs when the options cannot be evaluated according to the defined decision criteria. Another example of a possible loop, which is not plotted in the figure, refers to Fig. 6.4. In the case of two successive subproblems, it is possible that no satisfactory solution is found for the second subproblem. In this case, it is possible that the solution of the first subproblem must be reexamined.

Different general heuristic problem-solving procedures can be found in the literature (e.g., Bazerman and Moore 2009, pp. 1 ff.; Jennings and Wattam 1998, pp. 5 ff.; Robbins et al. 2011, pp. 84 ff.). A common feature is that the problem-solving task is divided into steps, as in the proposal made here. There are differences, however, in the delimitation of the steps and in their order.

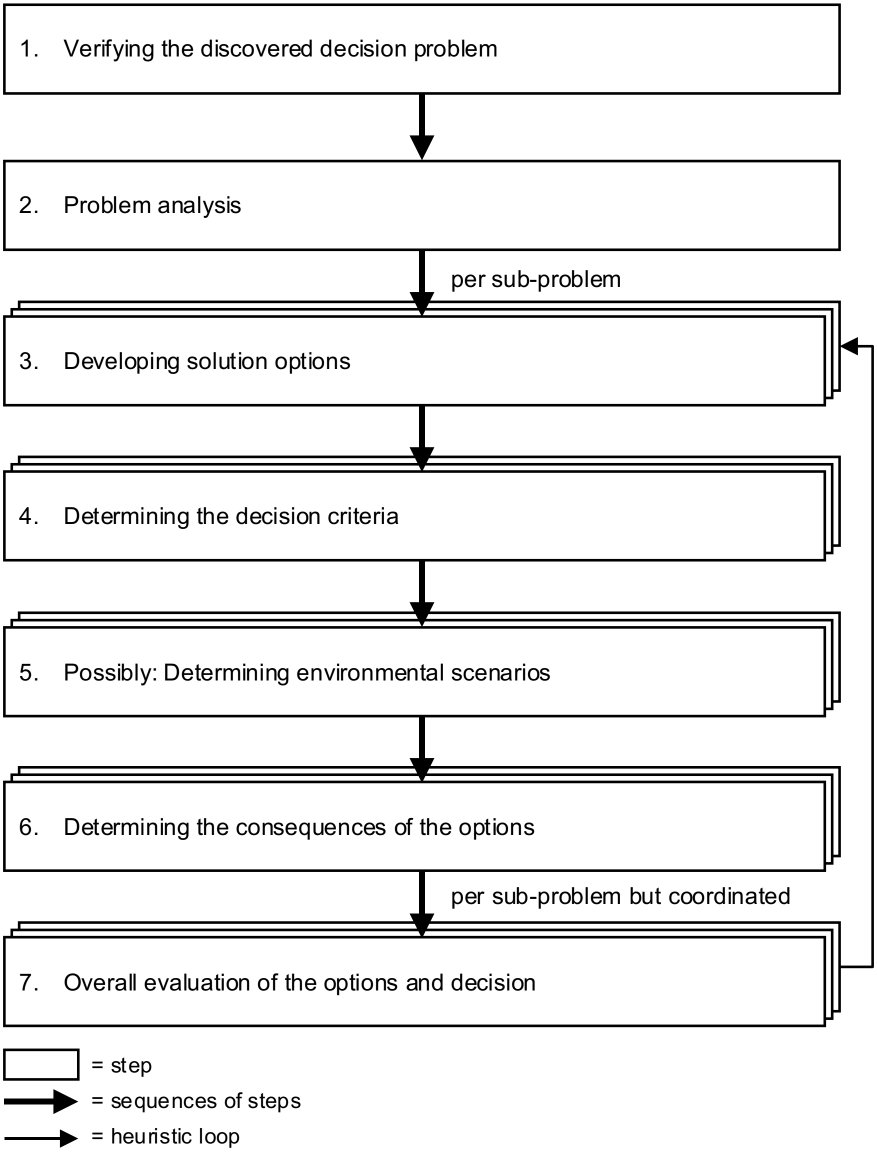

Fig. 6.1 The general heuristic problem-solving procedure in its basic form

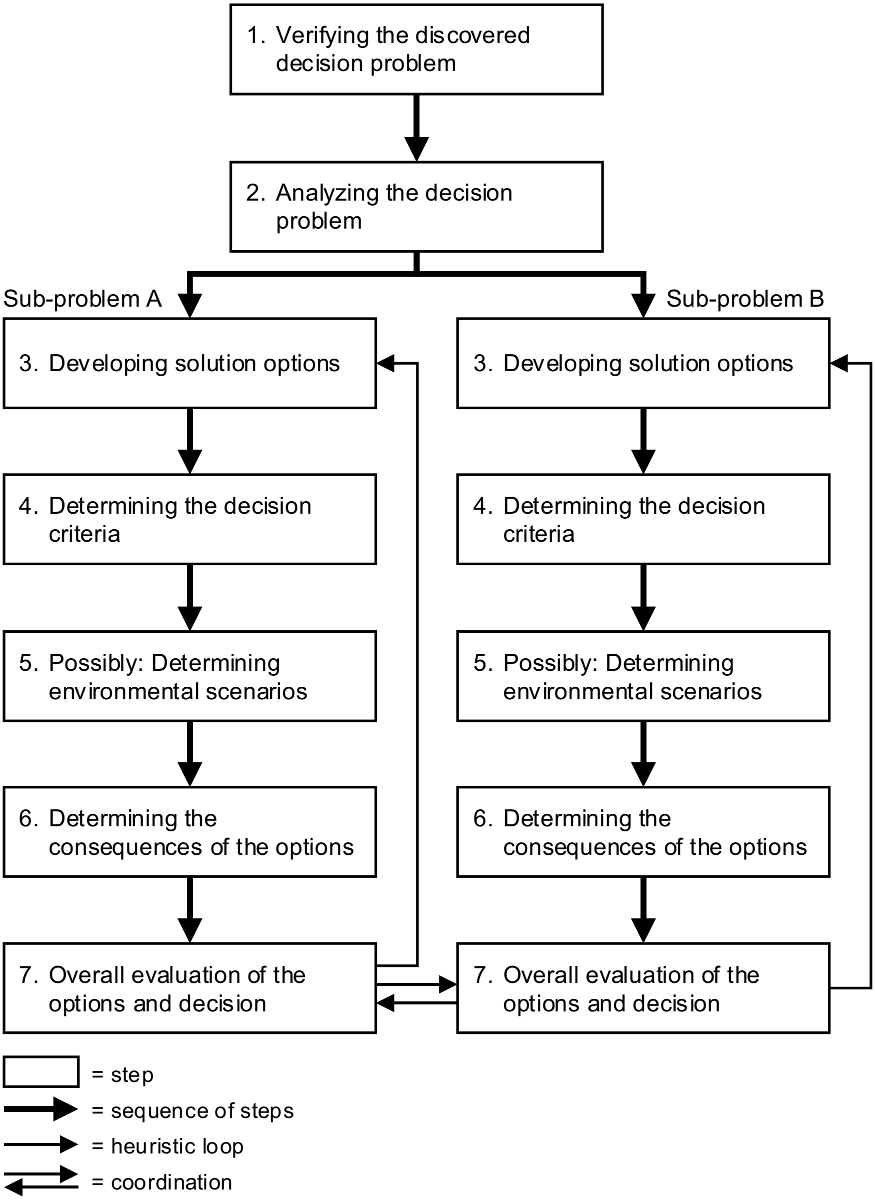

Fig. 6.2 The general heuristic problem-solving procedure when solving subproblems in parallel

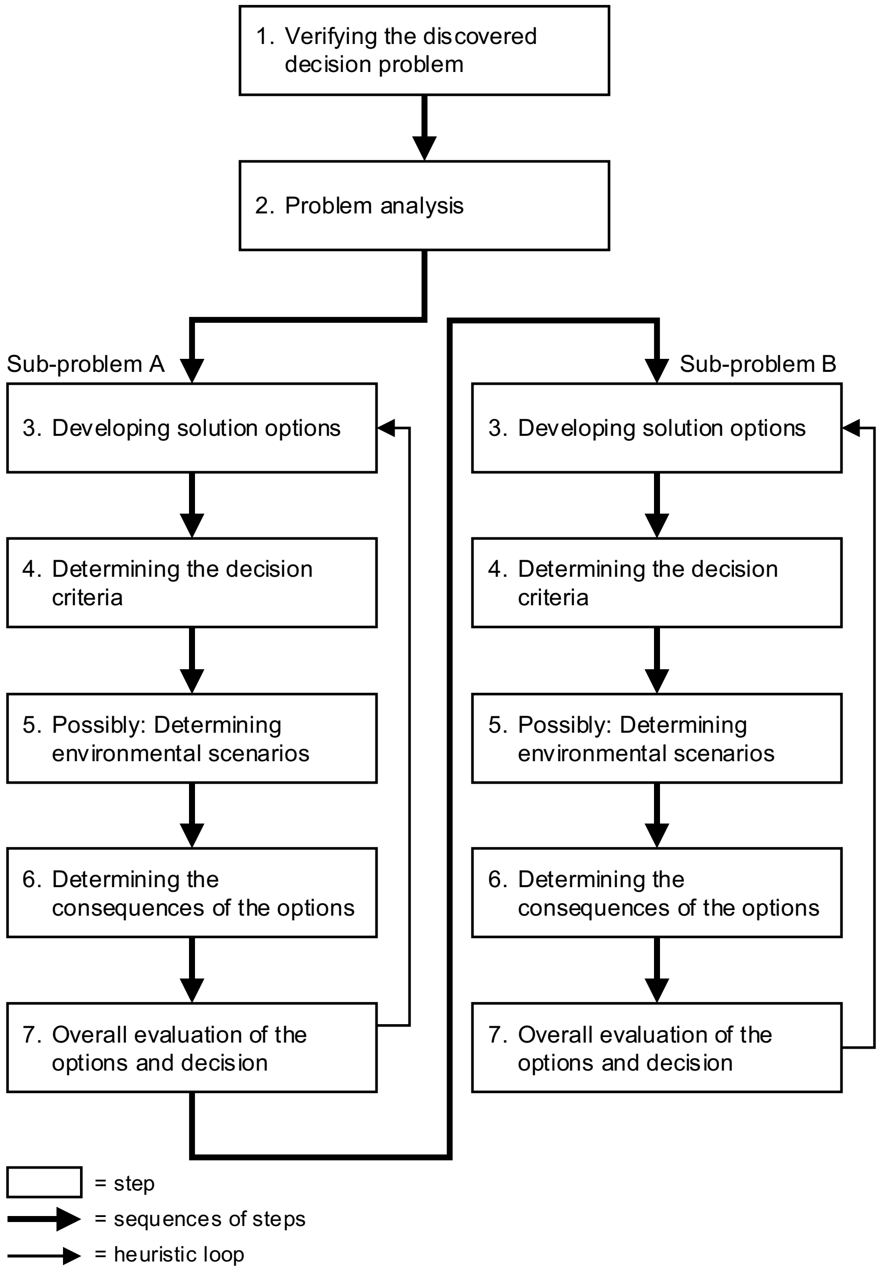

Fig. 6.3 The general heuristic problem-solving procedure when solving subproblems in succession

6.3 Brief Explanation of the Steps

After presenting the structure of the general heuristic problem-solving procedure in Sect. 6.2, the proposed steps are briefly explained in the following text. This gives the reader an overview of what is involved in working through the application of the procedure.

The problem-solving process begins once a decision problem has been identified, either ad hoc or with the help of a problem-finding system (see Chap. 3). It begins in Step 1 with the verification of the discovered decision problem. Here, the actor must check whether the discrepancy between the target and current situation is based on reliable information and is significant enough to tackle.

In Step 2, the problem is analyzed. This step begins with a summary of the initial situation. In the case of a threat problem, the causes of the problem must then be determined. Finally, the problem is broken down into subproblems, and their processing is determined.

Steps 3–7 are completed for each subproblem. Whether the subproblems are tackled in parallel or sequentially depends on the problem structure determined in Step 2.

Step 3 involves the development of at least two solution options. If it is impossible to identify two essentially different solution options—options that do not differ only in matters of detail—there is no decision. However, this is a rare exception from the authors' point of view. In most cases, several solution options can be found to eliminate or reduce the difference between the target and the current situation.

In Step 4, the actor must then determine the decision criteria for evaluating the problem-solving options. Contrary to goals, which are usually rather vague descriptions of the target situation, the decision criteria define specific assessment standards.

After establishing decision criteria, the actor must deal in Step 5 with the question of whether the options have reliable consequences or whether their assessment must be carried out in parallel for different environmental scenarios. If the consequences must be determined in parallel for several scenarios, they must be determined. As far as possible, probabilities should be assigned to the various scenarios.

Step 6 contains the determination of the single consequences for each option, for each decision criterion, and possibly for each environmental scenario.

Finally, the options are assessed in Step 7. This overall assessment of the options can be carried out summarily or analytically. If the actor decides to proceed analytically, he needs methodological rules to determine the overall consequences. These rules are known as decision maxims.

Figure 6.4 summarizes these explanations with a simple example. This concerns the insufficient return of a manufacturer of kitchen appliances focused on the Swiss market.

1. Verifying the discovered decision problem	over 7% return (target) — (current) only 4% return
2. Problem analysis	Sub-problem 1: Too much turnover in retail chains; Sub-problem 2: Too high stocks; Sub-problem 3: Too high labor costs in manufacturing
per sub-problem	e.g. Sub-problem 3: Too high labor costs in manufacturing
3. Developing solution options	A = Rationalization of production at the existing plant in Switzerland B = Relocation of production to a new own factory in the Eurozone C = Outsourcing to a sub-contractor in the Eurozone
4. Determining the decision criteria	1 = Overall cost of the products 2 = Quality of the products
5. Possibly: Determining environmental scenarios	a = EUR/CHF exchange rate decreases b = EUR/CHF exchange rate is constant or increases
6. Determining the consequences of the options	(see table below)
7. Overall evaluation of the options and decision	B > A > C

Options	**Decision criteria**		
	1		2
	Environmental scenarios		
	a	b	-
	Consequences		
A	C_{A1a}	C_{A1b}	C_{A2}
B	C_{B1a}	C_{B1b}	C_{B2}
C	C_{C1a}	C_{C1b}	C_{C2}

Fig. 6.4 Simple example of applying the general heuristic problem-solving procedure

6.4 Basis of the General Heuristic Problem-Solving Procedure

After providing an overview of the proposed general heuristic problem-solving process in Sects. 6.2 and 6.3, the chapter ends by showing its basis.

As can be seen in Fig. 6.5, the general heuristic problem-solving procedure is based partly on contributions from the literature and partly on the experience of the authors.

There are three bases from the literature:

- With heuristic principles, the literature on heuristics provides important rules that must be considered when designing a heuristic problem-solving procedure. Inset 6.1 presents the heuristic principles (see Kühn 1978, pp. 129 ff.) central to the problem-solving procedure and shows how they have been considered in the procedure.

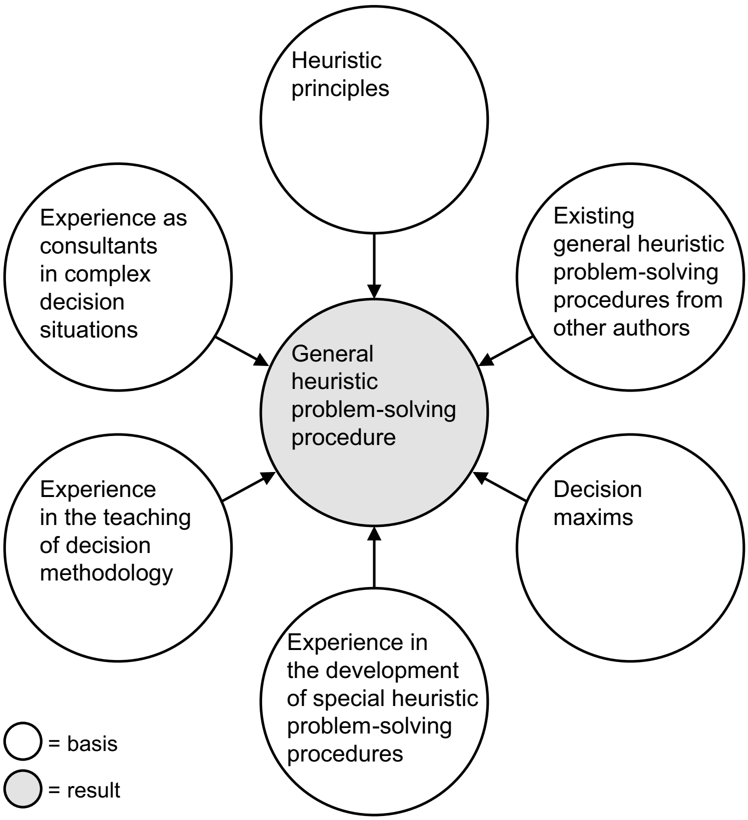

Fig. 6.5 Basis of the general heuristic problem-solving procedure

- As noted in Sect. 6.2, suggestions for general heuristic procedures exist in the literature. Comparing one's own ideas with these suggestions enables critical assessment and improvement of the proposed procedure.
- The decision maxims proposed in the literature for the analytical determination of the overall consequences form a further basis for the procedure. They are presented in Chap. 9.

The experiences of the authors can also be summarized in three points:

- While working individually and collectively, the authors designed several special heuristic problem-solving procedures. In doing so, the authors accumulated not only insights into the application of such procedures but also methodological knowledge. These were incorporated into the design of the proposed general heuristic problem-solving procedure.
- The teaching of general decision methodology also produced valuable findings. The methodological recommendations could be tested and improved in the context of case studies.
- Most valuable of all has undoubtedly been the experience as consultants to organizations facing significant and complex decision situations. Here, too, methods were applied and tested. What seems even more important is the knowledge gained on the situation and the feelings of top executives facing difficult decisions. They not only have an intellectual problem to solve but are also usually under enormous pressure to succeed. In addition, important decisions must often be made under time pressure. These aspects have also been considered in the design of the general heuristic problem-solving procedure.

Inset 6.1 Heuristic Principles and their Application

The inset is based on Kühn (1978, pp. 129 ff.).

Heuristic principles are, to put it simply, "thinking tricks" that problem solvers use to make complex problems solvable. The procedure proposed in this book primarily uses five heuristic principles. They, as well as their application, are described below.

Simon's principle of bounded rationality (1966, p. 19) is of great importance. It implies that there is usually no analytical problem-solving procedure for complex decision problems; therefore, the optimal solution cannot be determined. Consequently, the actor is forced to apply a heuristic problem-solving procedure and to be content with a satisfactory solution to the problem. The heuristic principle of bounded rationality is the basic assumption of the proposed problem-solving procedure.

The heuristic rule of factorization (see March and Simon 1958, p. 193) proposes to facilitate the solution of a complex decision problem by breaking it down into subproblems that can be solved in succession or in parallel. By dividing the problem into steps that can be tackled one after the other and partly in parallel, the principle is applied intensively.

Inset 6.1 (continued)

The principle of modeling (see Klix 1971, p. 724) requires that the sub-problems be delimited in such a way that known and proven methods to solve them are available. This principle mainly underlies the formation of Step 7: numerous decision maxims can be used to determine analytically the overall consequences of the options.

Another important heuristic principle is subgoal reduction (see Newell et al. 1965, p. 259). It suggests replacing general objectives that are difficult to apply for evaluating the solution options with more specific decision criteria that are easier for the decision-maker to apply. The principle forms the basis of Step 3.

The principle of generate-and-test (see Herroelen 1972, p. 227) recommends developing (generate) and evaluating (test) only one solution that appears to make sense, instead of developing and evaluating several options. If this solution fulfills the specified minimum goals, it is accepted as the solution to the problem. If the evaluation leads to an unsatisfactory result, the search for a solution must be continued. In the proposed procedure, the heuristic of generate-and-test is applied in the heuristic loop from Step 7 to Step 3: if the overall assessment produces an unsatisfactory result for all evaluated options, further options must be sought and assessed.

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7 Problem Verification and Analysis

7.1 Verifying the Discovered Decision Problem

7.1.1 Introduction

The starting point of every problem-solving process is the assumption that the overriding goals are not being reached (= threat) or that the overriding goals can be achieved better (= opportunity). The term "decision problem" therefore includes situations that are both negatively and positively assessed. This means that decision problems are understood in a neutral way.

In the context of the ongoing situation assessment (see Sect. 3.1), decision problems are discovered systematically or ad hoc. Each of them sets a problem-solving process in motion. It begins by verifying in Step 1 whether it really makes sense to deal with the problem. This verification prevents an investment of effort in processing a nonexistent or insignificant decision problem.

Problem verification includes different questions, depending on whether the problem is a threat or an opportunity.

7.1.2 Verifying a Threat Problem

In the case of a threat problem, the actor should clarify two questions before starting the problem analysis in Step 2:

- Is the identified difference between the target and the actual situation based on reliable information?
- Is the difference between the target and the actual situation significant?

The first question concerns the reliability of the information on the current situation:

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- Especially if the problem is discovered ad hoc, it is usually worth checking the quality of the information. For example, a visit to a sales subsidiary by the CEO may give the impression that there is a poor working atmosphere and that employees are not communicating openly. Before starting a problem analysis, another person, such as the HR manager, should revisit the subsidiary unannounced.
- However, even if a problem is discovered with the help of a problem-finding system, it can still be helpful to check the quality of the information. For example, if an interim financial statement shows a significantly worse result than expected, this may be due to one-off effects or incorrectly documented inventory changes. It is, therefore, worth checking the interim financial statement before initiating the problem analysis.

Secondly, the actor must ask himself if the difference between the target and the actual situation is significant and, therefore, worth working on the problem:

- If problem discovery is based on the use of a problem-finding system, the question can be answered without much difficulty. In this case, the actor normally has notions of "normal" and "abnormal" deviations. Figure 7.1 shows the example of

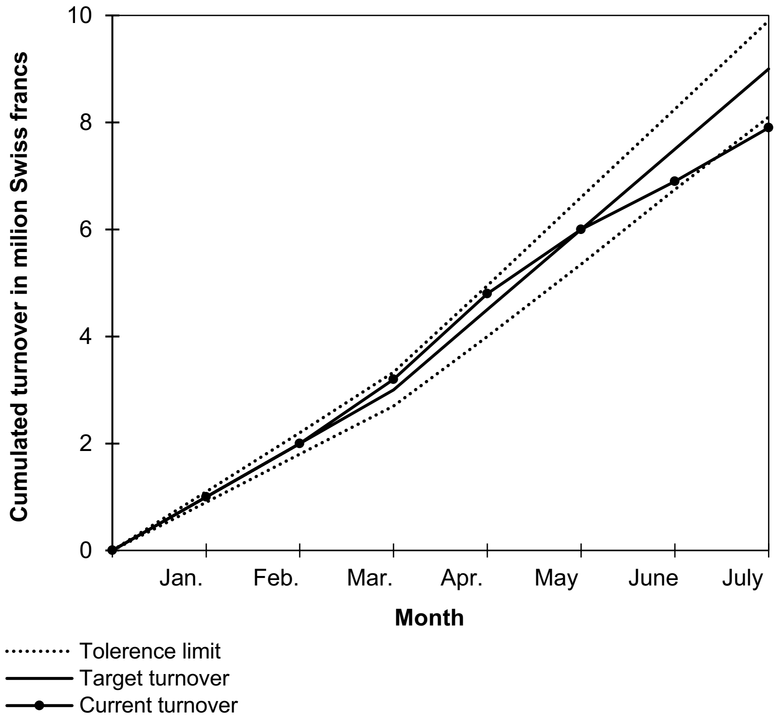

Fig. 7.1 Problem discovery on the basis of target cumulative turnover

problem discovery based on the cumulative target turnover of a product group. Deviations of ±10% are considered normal in this example and are shown by tolerance limits. Therefore, everything is in the "green zone" until the end of May. In June, the cumulative current turnover drops to the lower tolerance limit. In July, it falls below it, thus indicating a problem.
- If the problem is discovered ad hoc, it will be more difficult to answer the second question. In such cases, the target and current situations can typically only be described in vague terms. Accordingly, it is not easy to assess whether the difference is significant. Suppose the CEO of a producer of machines, for example, is faced at a trade show with a new generation of machines from his strongest competitor. In that case, it is difficult to assess the need for action for his own company. In addition to the new design, what is different about the machines? Are the technical improvements significant for the customers? Which customers would be willing to pay the higher price that the competitor asks for these improvements?

If one of the two questions is answered negatively, the problem-handling process should be aborted. In this case, the discovered decision problem cannot be verified, and the efforts associated with the further steps would not be justified.

7.1.3 Verifying an Opportunity Problem

In the case of an opportunity problem, verification comprises three questions:

- Is the identified difference between the target and actual situation based on reliable information?
- Is it an attractive opportunity?
- Is it an opportunity for the company?

As with a threat problem, the first question to be answered is whether the discovered difference between the target and actual deviation really exists. However, discovering an opportunity problem occurs more often than discovering a threat problem on an ad hoc basis. Accordingly, problem discovery is often based on qualitative information. This means that answering the first question in the case of an opportunity problem is generally more difficult than in the case of a threat problem.

The second question concerns the quality of the opportunity. In the case of a takeover bid, for example, the attractiveness of the markets in question and the competitive strength and profitability of the offered company must be assessed. It is obvious that such an assessment is generally difficult due to the limited information available.

The final question to be answered is whether it is an opportunity that the company can take advantage of. In the case of a takeover bid, the synergies must be assessed for this purpose. However, it is also necessary to answer the question of whether the takeover can be financed without the company having to take excessive risks.

An opportunity should only be pursued if all three questions can be clearly answered in the affirmative. Otherwise, no further work should be done.

7.2 Problem Analysis

7.2.1 Introduction

The problem analysis in Step 2 aims to understand the problem discovered in Step 1 so that effective problem-solving options can be developed in Step 3. The problem analysis, therefore, does not solve the discovered and verified decision problem but only serves to describe it more precisely. However, the authors agree with Drucker that this task is more important and difficult than the subsequent problem-solving: "The important and difficult job is never to find the right answer; it is to find the right question" (Drucker 1954).

Problem analysis is, from the authors' point of view, the most important and simultaneously the most challenging step in the general heuristic problem-solving procedure:

- Without a good understanding of the problem, the solution options developed in the next step may focus on the wrong area or take the wrong direction. This error may be discovered and corrected during the evaluation of the options. In this case, only a lot of unnecessary work has been done. In some cases, however, the error is not brought to light in the further processing of the problem. In this case, the actor solves an insignificant side problem or designs approaches to exploit an opportunity that does not exist.
- Problem analysis is difficult because each complex decision problem has a different structure. For this reason, it is not possible to provide methodological support that is at the same time generally applicable and concrete. Therefore, only relatively abstract methodical recommendations can be offered, and the actor must rely on himself for most of the problem analysis.

Step 2, therefore, typically involves a complex task. It is worth breaking it down into subtasks, applying the heuristic principle of factorization, as shown in Fig. 7.2. The subtasks are explained in the following subsections.

7.2.2 Summarizing the Initial Situation

Substep 2.1 provides a clear and understandable summary of the initial situation of the discovered and verified decision problem. This summary depends on the specific decision problem and can take many forms. The following examples illustrate the great variety of possible types of summaries of the initial situation:

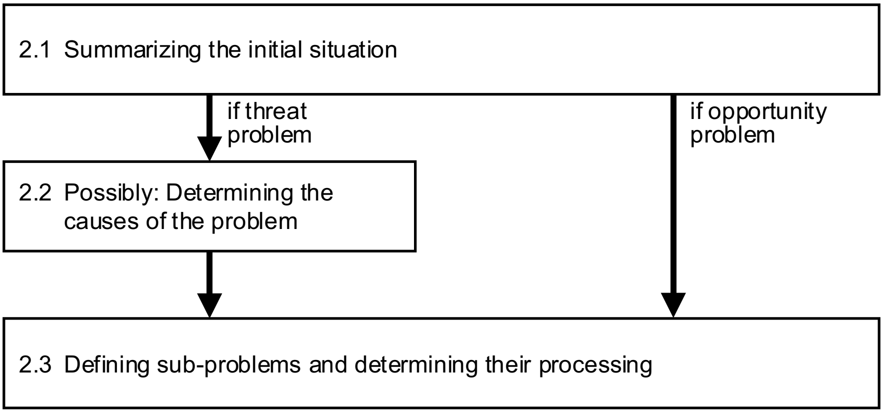

Fig. 7.2 Substeps of problem analysis

- If a management consultancy is to be commissioned to reduce the brand portfolio, an overview of the existing brands must be provided. In addition, a brief description should be given of why the current brand portfolio represents a problem from the company's point of view, what expectations are associated with the consultancy mandate, and what framework conditions need to be considered. Based on all this information, a specialized consulting firm should be able to submit an offer.
- If a consumer goods manufacturer notices declining sales and margins in the export business, the developments of sales and gross margins per export market and product group over the last years should be summarized in a table.
- Unclear tasks, competencies, and responsibilities and the associated conflicts within a management team can be documented by summarizing interviews with the members of the management team.
- If the discovered decision problem involves determining the further course of action in a legal dispute, a chronological reproduction of the events is a suitable summary of the initial situation.
- If the identified and verified decision problem relates to a new street accessing an industrial zone, the current traffic flows must be presented and quantified in a plan.
- The summary of the initial situation can also include a framework (see Osterloh and Grand 1994, pp. 97 ff.). If a technology group is offered a producer of photovoltaic systems by an investment bank, the information received and the initial considerations of "Strategic Development" can be summarized, for example, in the framework shown in Fig. 7.3.

It is not only the way of presenting the initial situation that varies, but also the approach to elaborate it. From the authors' point of view, there is no other subtask in the proposed problem-solving procedure that varies as much from one decision

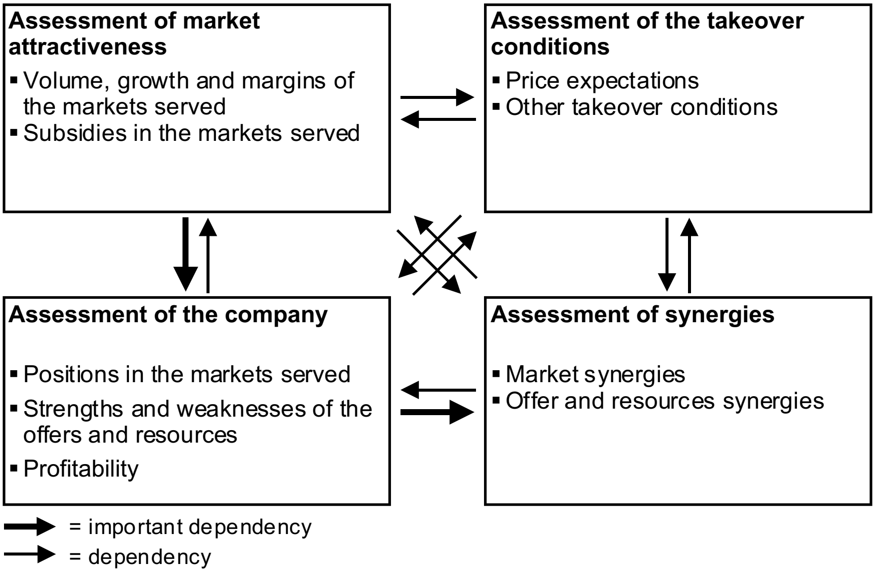

Fig. 7.3 Framework for the initial evaluation of the acquisition of a manufacturer of photovoltaic systems

problem to another as Substep 2.1. Consequently, no generally applicable procedure for dealing with this subtask can be proposed.

In addition to the form of the summary and the approach to elaborating it, the required effort also varies significantly from case to case. Sometimes, it is only a matter of compiling already known facts. In other situations, extensive data acquisition is necessary to summarize the initial situation.

7.2.3 Possibly: Determining the Causes of the Problem

A sustainable solution to a threat problem requires measures that eliminate the causes of the problem or at least reduce their negative impact on corporate goals. Actors who act without knowing the causes of the problem engage in symptom therapy. For instance, it is often the case that the stereotypical reaction to a loss of market share is to cut prices. This reaction takes place without knowing the causes of the loss of market share.

The causes of the problem are determined using a backward-moving problem indication. The discovered and verified problem is the starting point. The procedure for "backward-moving" is the following: on the basis of the discovered problem, all possible causes are listed. Then, as many of these causes as possible will be eliminated. The remaining causes are divided into possible subcauses. Here again, as many of these subcauses as possible are eliminated. This procedure is repeated until the actor can precisely say what led to the threat problem. Two methods of backward-moving problem indication frequently used in practice are the deductive tree and the DuPont analysis. They are briefly introduced below.

The deductive tree (see Hungenberg 1999, p. 25) is a generally applicable procedure for backward-moving problem indication. The procedure splits the discovered problem into subproblems. The actor then attributes the problem to one or a few subproblems and thus excludes other subproblems simultaneously. When constructing deductive trees, the following rules should be respected (see Hungenberg 1999, p. 22):

- Statements at the same level should not overlap but must exclude each other logically (= exclusiveness).
- Statements at one level must be completely covered by the statements at the next lower level (= exhaustiveness).

For example, suppose the identified problem is the sharp increase in staff turnover in the research department of a pharmaceutical manufacturer. In that case, the deductive tree might resemble the one in Fig. 7.4. As the example shows, with the help of a deductive tree, the discovered problem can be traced back, at least to some extent. Of course, the finding that the increase in turnover rates is mainly due to the departure of university graduates and university of applied sciences graduates does not yet represent a final problem diagnosis. A survey must now be conducted to determine why many qualified researchers leave the company.

The Ishikawa or fishbone diagram (see Joiner 1995) is presented differently than the deductive tree, but it is based on the same basic idea and the same two rules.

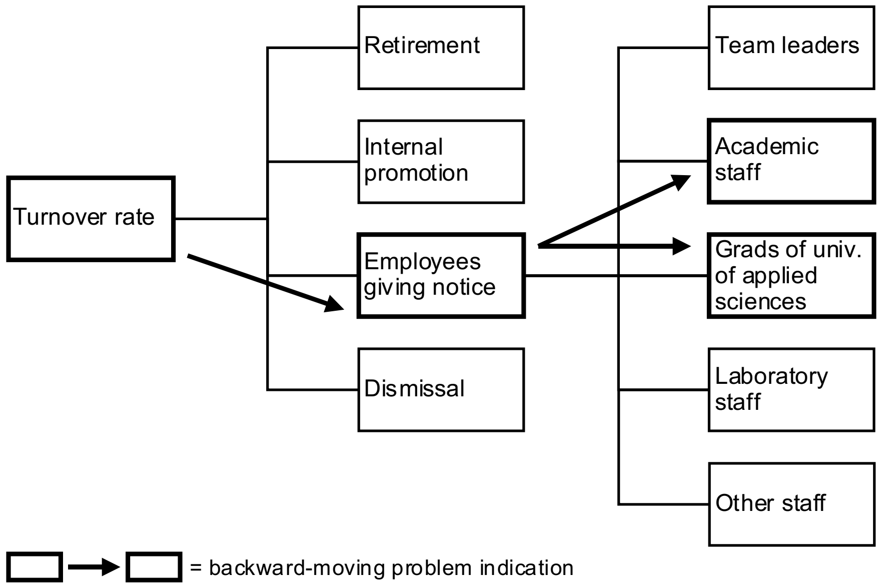

Fig. 7.4 Deductive tree to determine the causes of high staff turnover in a research department

If the discovered and verified problem is insufficient profitability, which is often the case, the backward-moving problem indication can be carried out with the help of the DuPont analysis of profitability. It breaks investment profitability down into return on sales and investment turnover. The two factors are then further divided into individual components (see Datar and Rajan 2018, pp. 914 f.).

Figure 7.5 shows an example. The deterioration in profitability can be attributed to a lower investment turnover, and this in turn to a sharp increase in raw material inventories. As in the example of the deductive tree, the problem analysis is not yet complete. It must now be determined why raw material inventories rose so sharply.

Determining the causes is very important for solving a threat problem. It is, therefore, worthwhile to work thoroughly and not just superficially. However, this can involve considerable costs. It may even be necessary to conduct an empirical survey to identify the causes of the problem with sufficient certainty. This was the case, for example, with a large public sector service provider that experienced difficulties in recruiting graduates from universities and universities of applied sciences. Those responsible were able to identify several possible causes. However, it was only possible to determine the actual causes by interviewing the graduates.

7.2.4 Defining Subproblems and Their Processing

Complex decision problems are characterized—among other things—by the fact that many measures are needed to reduce or overcome the difference between the target and the current situation. The actor would be overwhelmed if all these necessary measures had to be considered and assessed simultaneously. Therefore, applying the heuristic rule of factorization (see Inset 6.1) and splitting the problem into subproblems is recommended. Steps 3–7 are then completed separately for each subproblem. This increases the probability that these steps are successfully tackled.

The definition of subproblems must be solution-oriented. This means that the actor should define the subproblems so that well-known procedures, proven models, and existing experience can be resorted to during their subsequent solution. Defining subproblems in this way corresponds to the heuristic principle of modeling (see Inset 6.1). It usually facilitates the appointment of a suitable person responsible for solving the subproblem.

Finally, the further processing of the subproblems must be set. Here, two aspects must be considered:

- First, factual interdependencies should be considered. The solution of a subproblem may only be possible based on the solution of another subproblem. This is, for example, the case in the following situation: in a company, a problem of insufficient motivation of the sales force is discovered. The problem analysis reveals two causes: on the one hand, there are unclear goals for the sales force. On the other hand, there are insufficient salary incentives because profit-sharing is too low. As an incentive system ensures better achievement of goals, there is a

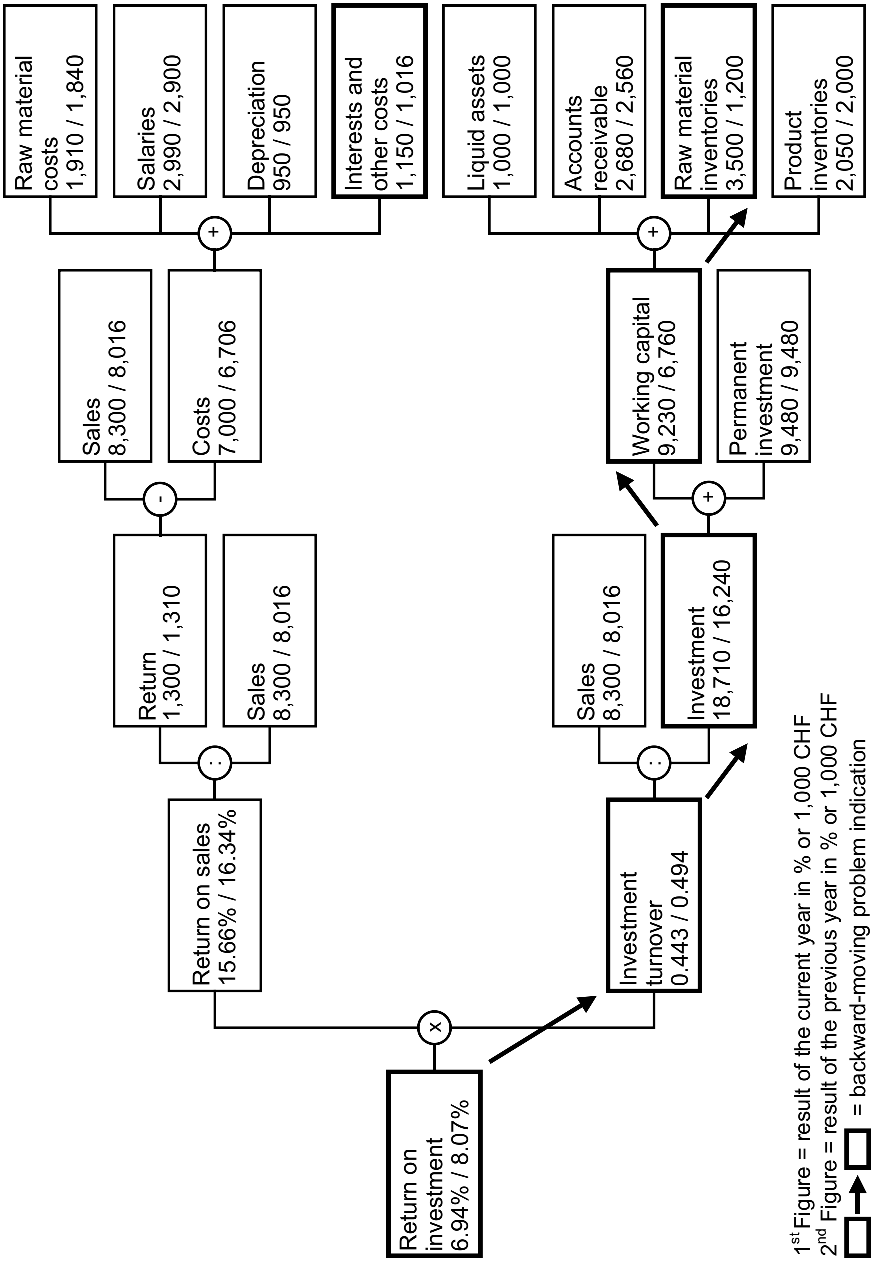

Fig. 7.5 DuPont analysis to determine the causes of an insufficient return on investment

clear consequence in this case: first, the subproblem of the goals and then the subproblem of the incentive system must be solved.

- Secondly, the urgency of the subproblems must be taken into account. This is, for example, the case in the following situation: a working capital that is too high and a low level of automation are identified as the causes of insufficient profitability. Working capital should be quickly reduced by reducing debtors and inventory, because "quick wins" are possible here. Increasing the degree of automation, however, requires comprehensive studies and investments.

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8 Developing and Evaluating Solution Options

8.1 Developing Solution Options

8.1.1 Introduction

The development of solution options represents the third step in the general heuristic problem-solving procedure. Like the other steps in the procedure, this task must be carried out for each subproblem defined in Substep 2.3 (see Subsection 7.2.4). As Fig. 8.1 shows, the development of solution options can be divided into three subtasks, which are described below.

8.1.2 Possibly: Determining Boundary Conditions

It is possible to define boundary conditions that the solution options must fulfill. For example, a maximum investment amount can be defined for rationalizing production. It is also possible that boundary conditions apply in general. The company policy of a clothes distributor can, for example, stipulate that it can only purchase from producers whose factories have been audited for compliance with social standards.

Boundary conditions reduce the effort involved in developing solution options. They can also avoid frustration caused by developing solution options that later turn out not to be feasible.

However, boundary conditions do not have only advantages. They can exclude innovative and radical solutions and therefore prevent thinking “out of the box.” The more restrictive the boundary conditions are, the more likely it is that solution options will be limited to optimizing what already exists. This is often insufficient to solve a problem in a sustainable way. The actor should therefore be restrictive when formulating boundary conditions.

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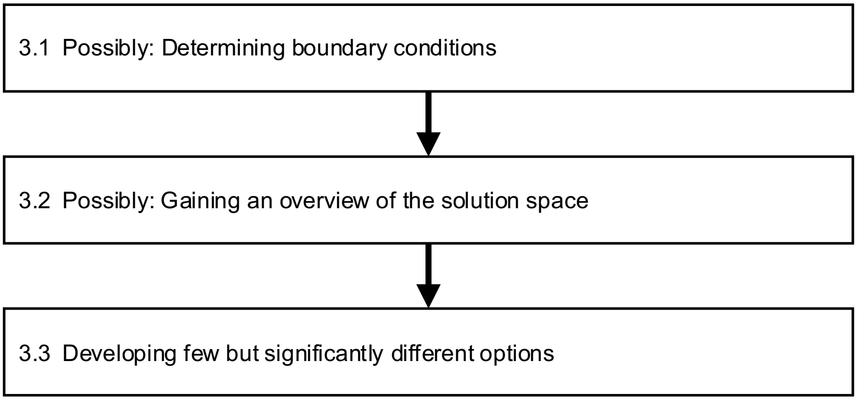

Fig. 8.1 Substeps for developing solution options

8.1.3 Possibly: Gaining an Overview of the Solution Space

The actor must be able to select between different solution types to ensure a high quality of problem-solving. To meet this requirement, the options in question must cover the solution space well.

If the actor does not have an overview of the solution space, it is worth systematically compiling the dimensions of the solution space and their possibilities in Substep 3.2. A good approach for this is the morphological box of Zwicky (1966, pp. 14 ff.). It is a matrix that provides an overview of an object's dimensions and their possibilities. On the vertical axis, the dimensions of the considered object—in our case, the decision dimensions—are listed. On the horizontal axis, the possibilities of the decision dimensions are listed.

Figure 8.2 shows the morphological box of a group that intends to put the decentralized employees of the group headquarters in one building.

8.1.4 Developing Few but Significantly Different Options

At least two options should be developed to allow the actor to make a choice. However, this requirement seems more demanding than it is: if the continuation of the status quo is a possibility, only one supplementary option is needed.

The inclusion of the status quo offers methodological advantages: it is generally easier to determine the consequences of the status quo than those of the new options. Therefore, it can make sense to use the status quo as a reference and to estimate the differences in consequences for the new options.

To be able to select a good solution in Step 7, the options developed in Step 3 should cover the solution space well. If only a part of the solution space is covered by options, the optimal solution may lie in the remaining space. Accordingly, the chosen solution would be far from the optimum. Figure 8.3 illustrates this statement.

Dimensions	**Possibilities**		
Location in the town	Center with link to public transport	Outskirts with parking places and link to public transport	Outskirts with parking places
Capacity	Current demand	Current demand plus 20%	Current demand plus 40%
State	New	Existing but with complete refurbishment	Existing and renovated
Image	Extraordinary architecture		Standard building
Ownership	Owned by the company		Longterm renting contract

Fig. 8.2 Morphological box for a new group headquarters building

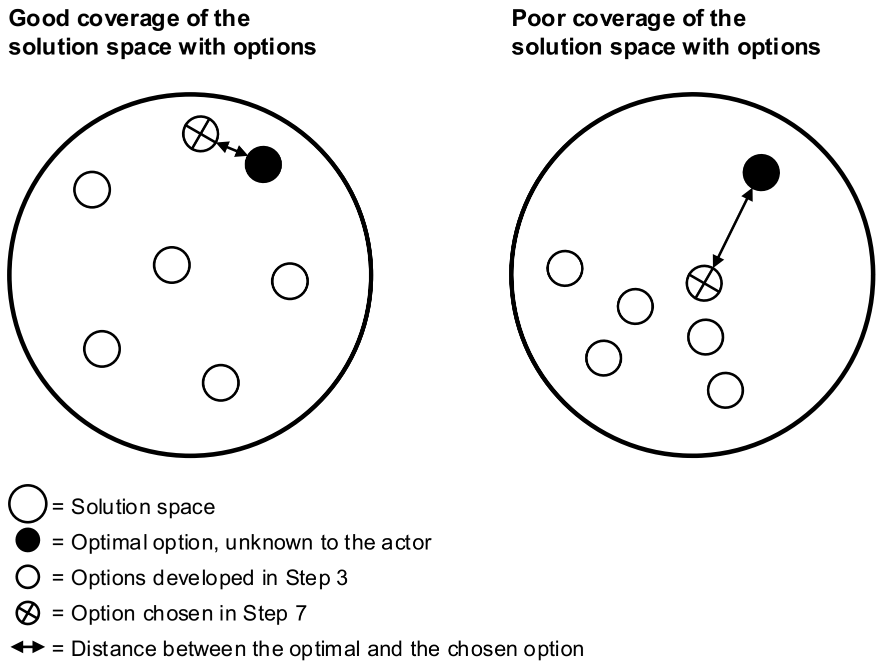

Fig. 8.3 Good and poor coverage of the solution space with options

However, good coverage of the solution space does not mean developing an enormous number of options. For each subproblem established in Step 2, from a practical point of view, three to four, but at most six, solution options should be developed and assessed. With a higher number of options, the following steps become more time-consuming and costly. At the same time, the quality of the solution selected in Step 7 increases only marginally.

Depending on the problem, developing the options may require creativity and unconventional ideas. This is, for instance, the case when developing alternative advertising concepts or new technical solutions for a packaging problem. In such cases, literature proposes using creative techniques like brainstorming, brainwriting, synectics, etc. (see, for instance, Nöllke 2012).

8.2 Determining the Decision Criteria

8.2.1 Introduction

As goals are often formulated rather vaguely, they must be specified before they can be used to assess options. Therefore, in Step 4 of the general heuristic problem-solving procedure, decision criteria should be defined.

A decision criterion is the concrete formulation of a goal in view of evaluating the options in a specific decision problem. Often, several decision criteria must be defined to measure the effects of the options on one goal.

The relationship between a goal and decision criteria will be explained using an example:

- The goal is high product quality.
- A distributor of power tools can measure product quality in its product range decision using the following decision criteria: number of functions, ease of use, safety, and susceptibility to repair.
- When purchasing a machine, a manufacturer of precision parts could use the following decision criteria to assess the quality of the machines under discussion: accuracy, degree of automation, and safety.

The decision criteria are determined in Step 4 in three substeps, as shown in Fig. 8.4. The three substeps are explained in the following subsections.

8.2.2 Clarifying the Pursued Goals

Companies usually pursue several goals simultaneously (see Sect. 3.2). Regarding a specific decision problem, not all goals are generally relevant. It is therefore important, before defining the decision criteria, to clarify which goals the company wants to pursue in the specific decision problem.

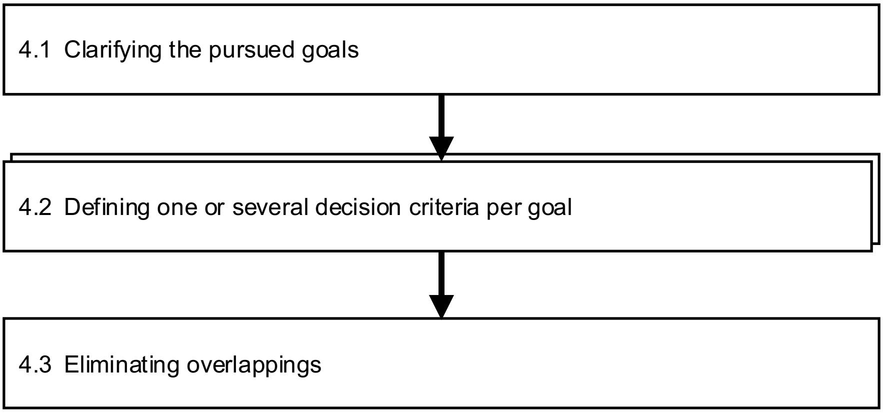

Fig. 8.4 Substeps for determining the decision criteria

The task of Substep 4.1 is normative in nature. No methodological recommendations can be offered.

8.2.3 Defining One or Several Decision Criteria per Goal

Based on the goals pursued, the decision criteria are set in Substep 4.1. A decision criterion must satisfy two conditions:

- On the one hand, the criterion must cover the represented goal or a part of the represented goal. The goal of high customer loyalty can, for instance, be measured via the repurchase rate and via the willingness of customers to recommend the supplier. As the two criteria measure different aspects of customer loyalty, it seems appropriate to use both criteria simultaneously in this example.
- On the other hand, a decision criterion should allow options to be evaluated. This demands a precise idea of what is meant by a decision criterion. This idea must be shared by all the people involved in solving the decision problem.

Depending on the decision criterion, the consequences of the options can be measured using a ratio scale (e.g., "investment expenditures" for the assessment of capacity expansion options), an interval scale (e.g., "temperature" to assess different types of district heating plants), or an ordinal scale (e.g., "location" to assess shop locations) (see Anderson et al. 2008, pp. 6 f.). If an ordinal scale is used for the measurement, the scale must be determined in addition to the decision criterion. For example, it can be determined that the locations of shops are assessed with "very good," "good," "sufficient," and "poor." Without this specification, the uniform assessment of options is not possible, and therefore the second requirement for a decision criterion is not met.

8.2.4 Eliminating Overlappings

In complex decision problems, the evaluation of the options is almost always based on several decision criteria. These criteria should be largely independent of each other; that is, they should not overlap. Otherwise, the actor uses two different criteria—often without realizing it—to measure the same effects of the options. Thus, options that meet these criteria well would be preferred.

For example, to assess shop options, the rent per m^2 and the occupancy costs per m^2 should not be used simultaneously as decision criteria. As the rent is an important component of occupancy costs, it would be used twice to assess the options.

To eliminate overlappings, common sense is necessary. Easy-to-use methods do not exist.

8.3 Possibly: Determining Environmental Scenarios

8.3.1 Introduction

The consequences of the options depend not only on the options themselves but also on the environment. For example, the profitability of a new sales subsidiary is, on the one hand, the result of the chosen location. On the other hand, profitability will also depend on the economic situation in the region and the reaction of competitors. Therefore, before determining the consequences in Step 5, the actor must deal with the environment and decide whether the consequences of the options are to be determined for different environmental scenarios. If the answer is yes, the scenarios must be determined.

Step 5 is divided into three subproblems according to the heuristic rule of factorization. Figure 8.5 shows the three resulting substeps, which are explained in the following subsections.

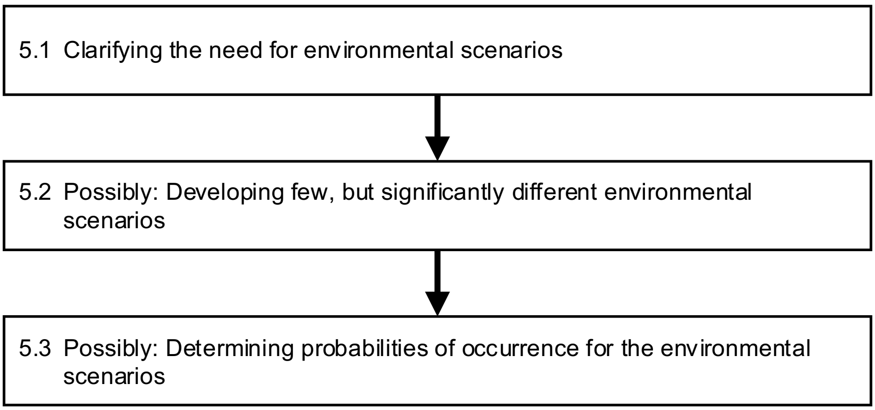

Fig. 8.5 Substeps for determining the environment scenarios

8.3.2 Clarifying the Need for Environmental Scenarios

The development of the environment can never be predicted with 100% certainty. However, there are decision problems in which the future development of the environment can be estimated with some degree of reliability. Courtney et al. (1997, pp. 68 ff.) refer to this situation as "A clear enough future." In this case, it is justifiable to determine the consequences of the options directly and omit environmental scenarios. In other decision problems, the actor cannot predict the development of the environment. As Courtney et al. (1997, pp. 68 ff.) put it, he is faced with "A range of futures." In this case, it would be reckless to make the decision on the assumption of one environmental development and ignore the other possible developments. The actor would be assuming a false sense of certainty. "It isn't what we don't know that gives us trouble, it's what we [mean to] know that ain't so" (Rogers 2022).

There are decision problems in which it is clear whether there is "A clear enough future" or "A range of futures." However, it often needs to be clarified whether there is slight or significant uncertainty regarding the future development of the environment. In these cases, the problem-solving team is recommended to discuss the future development of the environment. If the discussion reveals a broad consensus regarding this development, this is the case of "A clear enough future"; the development of scenarios can be omitted. If, contrarily, different views emerge, this is a case of "A range of futures," and environmental scenarios must be developed (see Grünig et al. 2022, pp. 76 f.).

8.3.3 Possibly: Developing Few but Significantly Different Environmental Scenarios

Suppose the actor concludes in Substep 5.1 that the development of the environment is uncertain. In that case, a few significantly different environmental scenarios must be developed in Substep 5.2.

The authors recommend a procedure based on Schwartz (1991, pp. 226 ff.) and van der Heijden et al. (2002, pp. 202 ff.) to develop the environmental scenarios. It consists of five tasks:

- First, all relevant environmental factors in the context of the decision problem must be identified. A suitable method for this is the PESTEL analysis (see Grünig et al. 2022, pp. 69 ff.).
- The identified environmental factors must then be ranked according to their importance and the predictability of their future development.
- The next task is to select one or two factors with high significance and poor predictability. However, not more than two factors should be selected, as otherwise too many environmental scenarios will result.
- For the selected factor, or respectively the two selected factors, a few clearly distinguishable characteristics must then be determined. In the case of one envi-

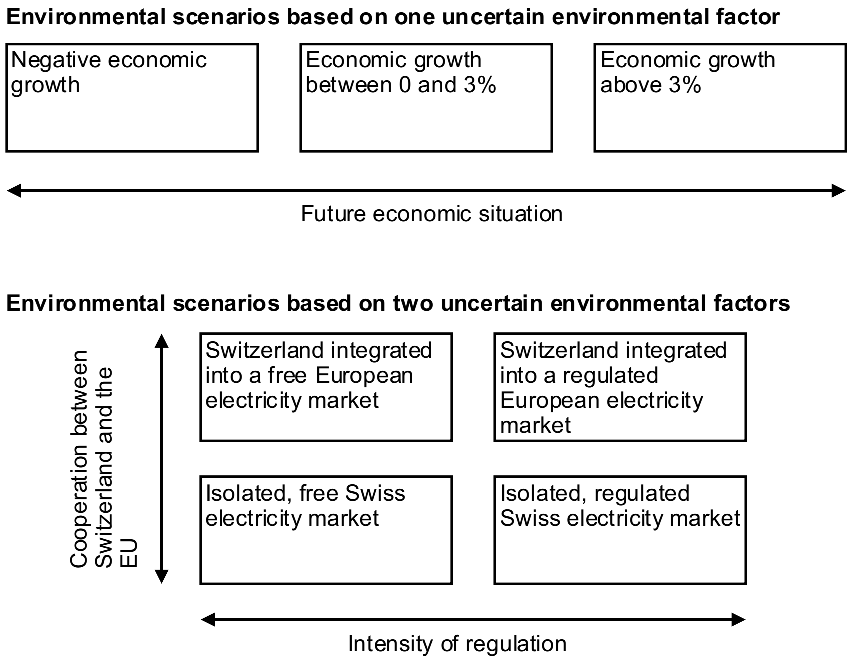

Fig. 8.6 Examples of environmental scenarios

ronmental factor, these form the environmental scenarios. In the case of two environmental factors, the scenarios consist of the combinations of the characteristics. Figure 8.6 shows two examples of environmental scenarios. The first example shows three scenarios that were used for the assessment of capacity expansion options. The second example illustrates the four environmental scenarios on which the selection of the future strategy of a Swiss electricity company was based.

- Finally, if necessary, the environmental scenarios should be described. "Scenarios are [often] narratives of alternative environments" (Ogilvy and Schwartz 1998, p. 1). With reference to the two examples shown in Fig. 8.6, a description seems unnecessary in the first example. However, such a description may be helpful in the second example so that all parties involved understand the environmental scenarios similarly when assessing the decision options.

8.3.4 Possibly: Defining Probabilities of Occurrence for the Environmental Scenarios

Finally, in Substep 5.3, it must be checked whether probabilities can be assigned to the environmental scenarios. The assignment of probabilities is not compulsory and

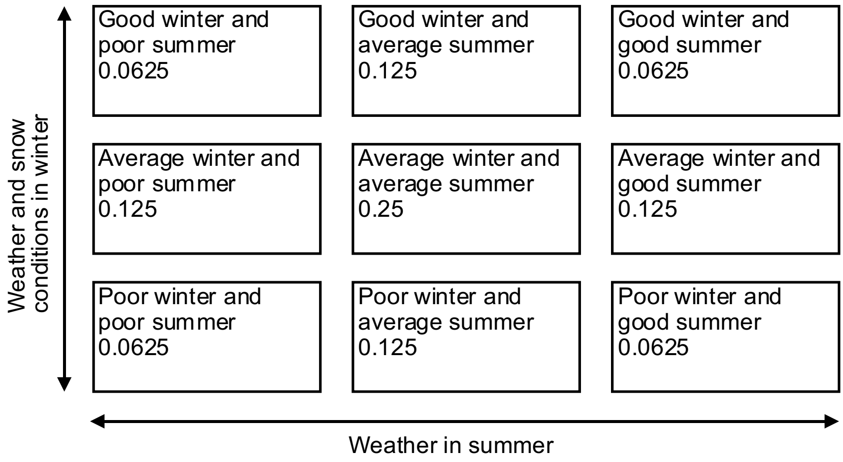

Fig. 8.7 Weather scenarios with their probabilities

should therefore only be carried out if it can be supported by facts. Incorrect probabilities would lead to wrong decisions.

For example, if weather scenarios are defined as a basis to assess mountain railway projects, probabilities can be assigned to them based on meteorological data. Figure 8.7 shows an example with nine environmental scenarios and their probabilities of occurrence.

8.4 Determining the Consequences of the Options

8.4.1 Introduction

The relevant outcomes of an option are referred to as its consequences. As Fig. 8.8 shows, the consequences begin once the decision has been made and normally last much longer than the implementation of the selected option.

The determination of the consequences of the options forms Step 6 in the general heuristic problem-solving procedure. Figure 8.9 shows the three substeps for determining the consequences of the options. They are described in the following subsections.

8.4.2 Creating the Decision Matrix

In Steps 3, 4, and 5, the options, the decision criteria, and, if necessary, the environmental scenarios were defined in turn. These three elements enable the creation of the decision matrix as the basis for determining the consequences. It defines the single consequences to be determined in Substep 6.2.

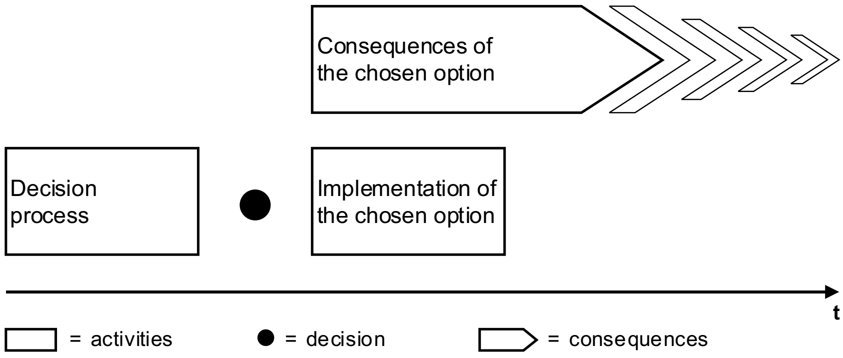

Fig. 8.8 Consequences of the chosen options

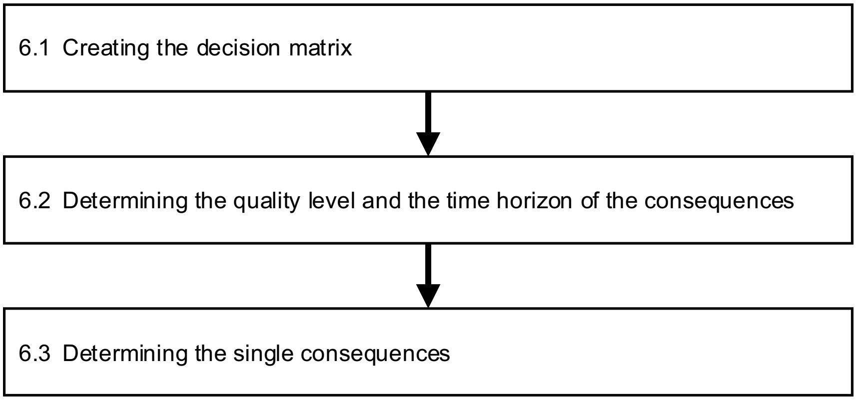

Fig. 8.9 Substeps for determining the consequences of the options

Figure 8.10 shows an example. The decision problem concerns the business expansion of a family company owned by Polish immigrants. The company has only been active in Switzerland up to now. As the figure shows, four options must be assessed with the help of three decision criteria. For one of the criteria, the consequences depend on the economic situation in Germany and Poland.

For a decision problem to arise, at least two options are necessary. However, these options do not need to be evaluated against multiple criteria, as shown in Fig. 8.10:

- A univalent decision problem arises when the evaluation of the options is carried out based on a single decision criterion. A univalent decision problem also exists when multiple decision criteria are used to evaluate the options, but these stand in an arithmetical relationship to each other. This is the case, for instance, in evaluating options in an assortment decision using two decision criteria: “net

Criteria (C), weights (W), scenarios (S) and probabilities (P) / Options (O)	C_1: Discounted free cash flow in millions EUR		C_2: Creation of jobs in Poland (1)	C_3: Management capacity required (2)
	W_1: 0.7		W_2: 0.2	W_3: 0.1
	S_1: Good economic situation	S_2: Bad economic situation	-	-
	P_1: 0.6	P_2: 0.4	-	-
O_1: Buy manufacturer with production plants in Germany and Poland	c_{111}	c_{112}	c_{12}	c_{13}
O_2: Create sales agencies in Germany and Poland	c_{211}	c_{212}	c_{22}	c_{23}
O_3: No business expansion	c_{311}	c_{312}	c_{32}	c_{33}

c = single consequence
(1) = measured on an ordinal scale with the values “many”, “some”, “few” and “none”
(2) = measured on an ordinal scale with the values “high”, “low” and “none”

Fig. 8.10 Example of a decision matrix without single consequences

sales per unit” and “variable cost per unit.” The assessment of the options could equally well be based on the difference between the two criteria, that is, the contribution margin per unit.

- A multivalent decision problem exists if several criteria are used to evaluate the options and these criteria are not arithmetically related. Since the three criteria in the example in Fig. 8.10 are not in an arithmetic relationship, this is a multivalent decision problem.

The scenarios presented in Fig. 8.10 are also not mandatory. Three different situations can be distinguished:

- There are no uncertain environmental variables with a significant influence on the evaluation of the options. In this case, it is a decision under certainty.
- There are one or more uncertain environmental variables with a significant influence on the evaluation of the options. On this basis, the actor develops environmental scenarios to which probabilities of occurrence can be assigned. In this case, one speaks of a risk decision problem.

Environmental scenarios \ Criteria	Decision problem under univalence	Decision problem under multivalence
Decision problem under certainty	Decision problem under univalence and certainty	Decision problem under multivalence and certainty
Decision problem under risk	Decision problem under univalence and risk	Decision problem under multivalence and risk
Decision problem under uncertainty	Decision problem under univalence and uncertainty	Decision problem under multivalence and uncertainty

Fig. 8.11 Six decision constellations

- As in the situation described above, several environmental scenarios exist. However, no probabilities of occurrence can be specified for these. This is referred to as an uncertain decision problem.

Since decisions can be univalent or multivalent on the one hand, and under certainty, risk, and uncertainty on the other hand, there are six possible decision constellations. They are represented in Fig. 8.11.

8.4.3 Determining the Quality Level and the Time Horizon of the Consequences

In practice, it is useful to distinguish two quality levels when determining consequences:

- The determination of consequences can be based on empirical studies and forecasting models. For example, the effect of TV commercials can be determined using market research, or the demand for alternative prices can take place via statistically based demand functions.
- The consequences are estimated based on the knowledge of the actor. This subjective determination of consequences is based on the know-how of the actor.

The chosen quality level of the consequences depends on two factors:

- The importance of the decision problem: The more important the decision problem is for the actor, the more effort he will accept in assessing the solution options.

- The possibility to conduct empirical research or make forecasts: This is not always possible. Especially if the decision must be made under time pressure, the determination of consequences is often only possible based on subjective appraisal.

In most cases, consequences are estimated. An associated problem is that people normally overrate their knowledge and, therefore, tend to trust their subjective judgments too much. This tendency to overestimate one's own knowledge must be countered to achieve a reliable evaluation of options. The following measures appear to be useful:

- The consequences can first be determined independently by several individuals. Then, each person is confronted with the judgments of the others, and the differences are worked out. This process—similar to a Delphi study but much less costly—leads to a group judgment that is fundamentally better than the individual judgments. The group judgment is also better than the average of individual judgments because erroneous ideas are uncovered in the discussion and individuals can revise their judgments.
- Group discussion can be stimulated by asking disconfirming questions. These questions can, for example, challenge the experience on which the consequences are based, or they can question the assumptions underlying the consequences (see Russo and Schoemaker 1990, p. 103).
- Those responsible for determining the consequences should afterwards be confronted with the actual effects of the chosen option. Learning effects can be achieved in this way, and these will have a positive effect on a subsequent, similar decision problem (see Russo and Schoemaker 1990, p. 98).

As Fig. 8.8 schematically shows, a decision may have very long-term consequences. The acquisition of a competitor, for example, impacts the company's further development without a time limit. In many decision problems, it is, therefore, impossible to determine all the consequences of the options under discussion. In such a situation, the actor is forced to determine not only the intended quality of the consequences but also their time horizon. From a practical point of view, it seems important to choose a longer time horizon than the implementation of the options requires. In this way, the effects of the option after its implementation are included in the assessment.

8.4.4 Determining the Single Consequences

Once the quality level and the time horizon of the consequences have been defined, Substep 6.3 involves determining the single consequences of the options specified by the decision matrix. Figure 8.12 shows the decision matrix introduced in Subsection 8.4.2, with the single consequences of the options.

Criteria (C), weights (W), scenarios (S) and probabilities (P)	**C_1: Discounted free cash flow in millions EUR**		**C_2: Creation of jobs in Poland (1)**	**C_3: Management capacity required (2)**
	W_1: 0.7		**W_2: 0.2**	**W_3: 0.1**
	S_1: Good economic situation	**S_2: Bad economic situation**	-	-
Options (O)	**P_1: 0.6**	**P_2: 0.4**	-	-
O_1: Buy manufacturer with production plants in Germany and Poland	c_{111} = 16	c_{112} = -8.5	c_{12} = many	c_{13} = high
O_2: Create sales agencies in Germany and Poland	c_{211} = 10	c_{212} = -1	c_{22} = few	c_{23} = low
O_3: No business expansion	c_{311} = 0	c_{312} = 0	c_{32} = none	c_{33} = none

c = single consequence
(1) = measured on an ordinal scale with the values “many”, “some”, “few” and “none”
(2) = measured on an ordinal scale with the values “high”, “low” and “none”

Fig. 8.12 Example of a decision matrix with single consequences

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9 Overall Evaluation of the Options and Decision

9.1 Introduction

As a result of Step 6, the actor has a decision matrix that shows the single consequences of each option. Based on this, an overall evaluation of the options must now be carried out, and a decision must be made in Step 7.

The overall evaluation of the options and the decision made on this basis represent a complex task. Step 7 is therefore divided into substeps, as shown in Fig. 9.1.

In the case of a decision problem under univalence and certainty, each option has only one consequence. Figure 9.2 shows an example of such a decision problem: a trading company must decide which of three mutually exclusive products should be integrated into its range. As all three items are supposed to yield the same sales volume, the actor can decide based only on the contribution margins per unit. In this case, Substeps 7.1–7.3 are unnecessary, and the actor can directly make the decision.

9.2 Eliminating Irrelevant Options

An option can be excluded if it performs equally or worse than another option for all criteria and/or scenarios. It is irrelevant because there is a natural order. Eliminating irrelevant options reduces the effort required for Step 7.

Figure 9.3 shows an example of a natural order in a decision under multivalence and certainty. As the figure shows, machine A is inferior to machine tool B in three out of four criteria. As for "capacity," they are equal. Machine tool A can therefore be eliminated. The actor will therefore only have to decide between B and C.

Figure 9.4 shows an example of a natural order in the case of a decision under multivalence and uncertainty. Since only two options exist, and option B outperforms option A in every single consequence, it can be directly chosen.

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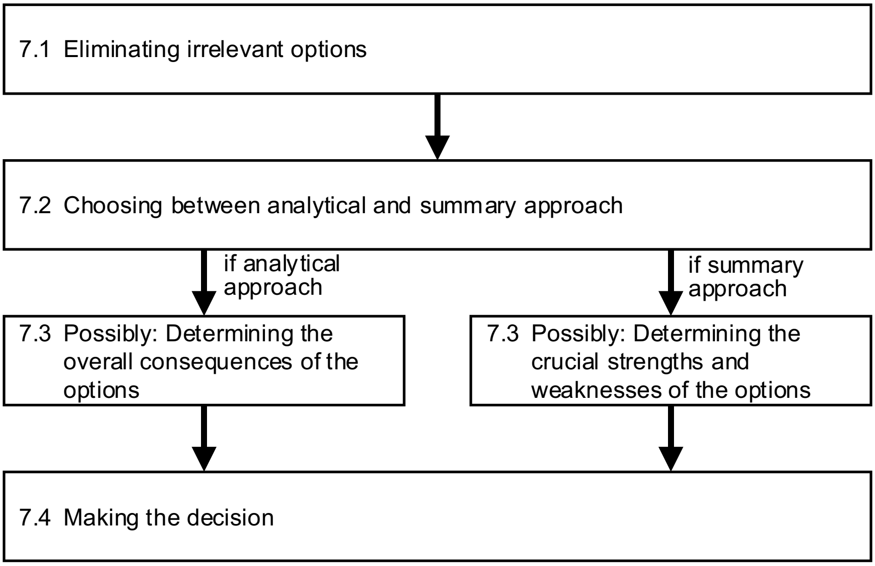

Fig. 9.1 Substeps for the overall evaluation of the options and decision

Options of products to be included in the range	Contribution margin per unit in Swiss francs as consequences
Product A	50
Product B	61
Product C	46

Fig. 9.2 Example of a decision problem under univalence and certainty

However, natural orders are also possible in three other decision constellations: univalence and risk, univalence and uncertainty, as well as multivalence and risk.

9.3 Choosing Between Analytical and Summary Approach

Based on the decision matrix that has been adjusted according to natural orders, two approaches are possible for the actor:

- The actor can proceed analytically and determine the overall consequences of the options by using decision maxims. Based on these overall consequences, he can then choose an option or reject all the options.

Criteria / Options	Investment in Swiss francs	Capacity in units/hour	Precision in mm	Safety level
Machine A	550'000	1'000	± 0.2	Good
Machine B	500'000	1'000	± 0.1	Very good
Machine C	380'000	1'050	± 0.15	Satisfactory

Fig. 9.3 Example of a natural order in a decision problem under multivalence and certainty

Criteria and scenarios / Options	Project costs in Swiss francs		Cumulated profits in the next five years in Swiss francs		Techno-logical gain
	Patenting succeeds	Patenting fails	Patenting succeeds	Patenting fails	
Development project A	480'000	440'000	1'250'000	625'000	High
Development project B	430'000	390'000	1'500'000	975'000	Very high

Fig. 9.4 Example of a natural order in a decision problem under multivalence and uncertainty

- The actor can summarily assess the options under consideration. He can either choose one of them or, using a heuristic loop, go back to Step 3 and develop new options.

Many books on problem-solving and decision-making implicitly presuppose choosing the analytical approach. From the authors' point of view, however, this falls short, given that both approaches have significant advantages and disadvantages. The choice between the analytical and summary approaches is therefore a genuine procedural decision that should be made consciously.

Determining the overall consequences using decision maxims takes into account the rules of formal logic and thus contributes to the formal rationality of the decision (see Sect. 4.3). This advantage is offset by the critical disadvantage that the overall consequence values are often difficult to interpret due to the arithmetic operations behind them. However, as Little (see Little 1970, pp. B-466 ff.) has shown, managers prefer to trust values whose origin they can understand when making far-reaching decisions.

The summary approach weighs up the single consequences of the options summarized in the decision matrix. This weighing up is inevitably subjective. However, in contrast to the arithmetic operations in the analytical approach, it leads to a conscious and therefore goal-oriented decision. As shown in Sect. 4.3, goal orientation is a condition of a formally rational decision.

In contrast to literature, which largely and frequently emphasizes the analytical approach, the authors prefer the summary approach. As for the analytical approach, it is important that the decision based on the overall consequences of the options is "supported" by intuition and experience.

9.4 Possibly: Determining the Overall Consequences of the Options

9.4.1 Description of Tasks

If the analytical approach is chosen in Substep 7.2, the overall consequences of the options must be determined in Substep 7.3 using decision maxims. Decision maxims are systems of rules for summarizing the single consequences of the options into their overall consequences. They are based on formal logic (see Sect. 4.3) and form a central part of decision logic (see Sect. 5.6).

9.4.2 Overview of Decision Maxims

Figure 9.5 provides an overview of the various decision maxims and their application. As can be seen from the figure, the decision maxims to apply depend on the decision constellation:

- In the case of univalence and certainty, no decision maxim is necessary. The consequences of the options are similar to their overall consequences (see Subsection 9.3).
- For decision constellations under univalence and risk, the expected value can be calculated. Bernoulli has developed a more sophisticated procedure that considers the actor's attitude to risk. It is also possible to apply the maxims of uncertainty. However, this is only possible if some information is ignored, since the different scenarios are considered but not their probabilities of occurrence.
- For decision constellations under univalence and uncertainty, three maxims—the maximax, Wald's minimax, and Laplace's equal probability—may be used as simple rules for establishing the overall consequences. Furthermore, Hurwicz's optimism–pessimism index and Savage and Niehans' minimax-risk rule may also be used, but these are more demanding maxims.
- With decisions under multivalence and certainty, the utility value procedure and the scoring models represent possible maxims.

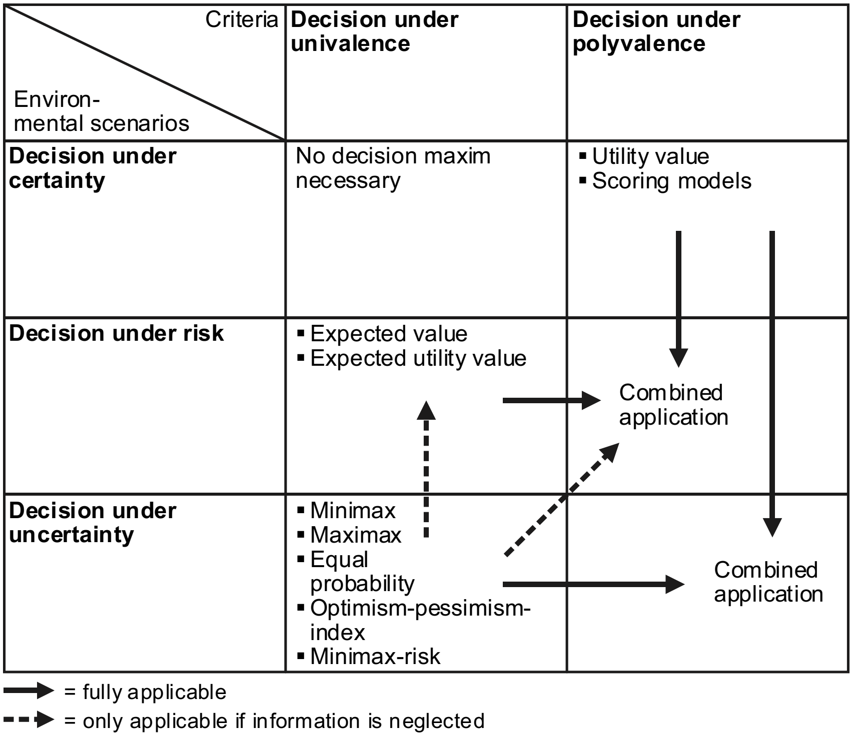

Fig. 9.5 The decision maxims and their application

- In the case of decisions under multivalence and risk, a maxim to overcome multivalence is combined with a maxim to overcome risk. Additionally, instead of using a maxim to overcome risk, it is also possible to use a maxim to overcome uncertainty. However, here again, information is ignored.
- Finally, decisions under multivalence and uncertainty need a combination of a maxim to overcome multivalence and a maxim to overcome uncertainty.

The maxims will be briefly presented below.

9.4.3 Decision Maxims for Overcoming Risk

As Fig. 9.5 shows, the maxims of expected value and expected utility value are available for overcoming risk.

In the case of risk, an obvious rule is to multiply the consequence values by their probabilities of occurrence and then add up the products for each option. The resulting sums are called expected values. The option with the best expected value is selected.

Criteria (C), scenarios (S) and probabilities (P) / Options (O)	C: Discounted free cash flow in millions EUR	
	S_1: Good economic situation	S_2: Bad economic situation
	P_1: 0.6	P_2: 0.4
O_1: Buy manufacturer with production plants in Germany and Poland	c_{11} = 16	c_{12} = -8,5
O_2: Create sales agencies in Germany and Poland	c_{21} = 10	c_{22} = -1
O_3: No business expansion	c_{31} = 0	c_{32} = 0

c = single consequence

Fig. 9.6 Decision problem under risk

Figure 9.6 illustrates a decision problem under risk.

The expected values are 6.2 for Option 1, 5.6 for Option 2, and 0 for Option 3. Option 1 should therefore be selected.

The expected value is only a suitable decision maxim if none of the single consequences involves a significant risk. Referring to the example, this means that the discounted free cash flow of EUR −8.5 million for Option 1 is assessed as “acceptable” by the actor in the case of a bad economic situation. If this is not the case, the maxim of expected utility value should be applied. The idea behind this maxim, which goes back to Bernoulli, is that the actor transforms the consequence values into utility values before calculating the expected value, incorporating his attitude to risk (see Bamberg and Coenenberg 2002, pp. 81 ff.; Bitz 1981, pp. 153 ff.; Rommelfanger and Eickemeier 2002, pp. 72 ff.). The application of this maxim includes two tasks:

- First, the consequence values must be transformed into utility values, which consider the risk attitude. The transformation of consequence values into utility values is normally carried out using a transformation curve.
- If the utility values are available, the expected utility value is then calculated in the same way as the expected value, and the option with the highest expected utility value is selected.

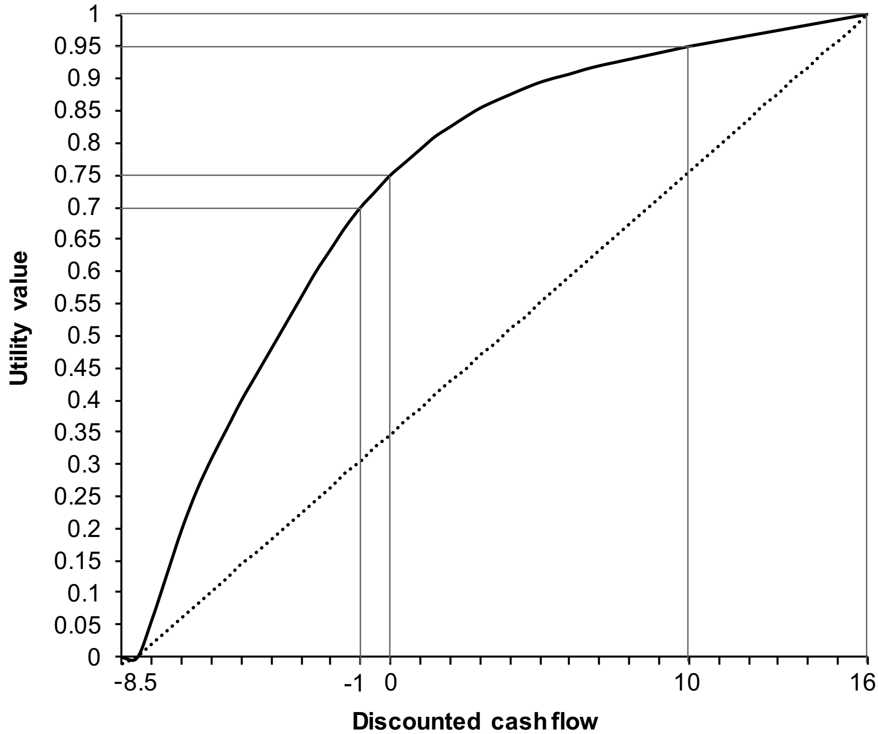

Fig. 9.7 Curve for the transformation of consequence values into utility values

Figure 9.7 shows the example of the transformation curve of an actor who converts single consequences into utility values. As can be seen from the figure, the lowest single consequence is always assigned the utility value of 0, and the highest single consequence the value of 1. The assignment of utility values to the other single consequences expresses the actor's attitude toward risk. The utility values for the individual consequences of EUR −1 million, EUR 0 million, and EUR 10 million are clearly above the diagonal. This means that the actor is risk-averse and rates the three single consequences significantly better than the lowest single consequence of EUR −8.5 million. The expected utility values of the three options can now be calculated by multiplying the utility values by their probabilities of occurrence and adding the resulting products. The expected utility values are 0.6 for Option 1, 0.85 for Option 2, and 0.75 for Option 3. In incorporating the attitude to risk, the actor chooses Option 2 with lower risk.

Correctly depicting one's own risk attitude in the transformation curve is nontrivial. This is probably the reason why the maxim of expected utility value is rarely applied in practice. As already discussed, since the application of the expected value is problematic, a maxim for overcoming uncertainty is often used. The maxims for overcoming uncertainty are partly very easy to apply. Nevertheless, this means that knowledge about the probability of occurrence is not considered.

9.4.4 Decision Maxims for Overcoming Uncertainty

Five decision maxims are particularly recommended for dealing with uncertain situations (see Bamberg and Coenenberg 2002, pp. 129 ff.; Bitz 1981, pp. 62 ff.; Laux 2002, pp. 106 ff.; Rommelfanger and Eickemeier 2002, pp. 51 ff.). They are:

- Wald's minimax maxim
- Maximax maxim
- Laplace's maxim of equal probability
- Hurwicz's optimism–pessimism index maxim
- Niehans and Savage's minimax-risk maxim

In the following text, these five maxims will first be briefly presented, and then their application will be explained using an example.

The minimax maxim compares options exclusively based on their worst consequences. The option that is best among these worst consequences is chosen. Applying the minimax rule corresponds to extreme risk-averse behavior or a worst-case attitude. The maximax maxim is exactly the opposite. It requires the actor to look only at the best consequences for each option and to go for the option that displays the highest value. The rule of equal probability represents a middle course between the minimax and maximax maxims. As its name suggests, it assumes that all single consequences are equally likely. The maxim, therefore, stipulates that an average consequence value must be determined for each option. The actor then chooses the option with the best of these values.

Like the maxim of equal probability, the optimism–pessimism-index maxim seeks a middle course between the extreme maximax and minimax rules. This maxim is applied in three steps:

1. First, the actor fixes a value for the optimism–pessimism index between 0 and 1. The higher the value, the more optimistic or risk-tolerant the actor is.
2. For each option, the best consequence value is multiplied by the index value, and the worst consequence value is multiplied by the difference between the index value and 1.
3. Finally, the two products are added. The option with the best value is chosen.

Niehans and Savage's minimax-risk maxim takes a fundamentally different approach. Unlike the other four maxims, it does not consider the single consequences from a more or less pessimistic or optimistic viewpoint but looks at the differences between the single consequences of the options in a scenario: if the actor decides in favor of option A and scenario 1 then follows, the actor is interested in the difference between the consequence of option A and the consequence of the optimal option in scenario 1. If this difference is great, there is at the same time great regret for having chosen option A. If the difference is small, the actor's regret is smaller. If the best option for the occurring scenario was chosen, then there is no reason for regret. The maxim tries to minimize the regret as much as possible. It is applied in three steps:

1. First, for each scenario, the differences between the consequences of the options and the best option are calculated. These differences represent the possible regrets of the options in the scenarios.
2. Then, the highest possible regret for each option is identified.
3. Finally, the actor decides in favor of the option where the highest possible regret is the lowest.

Figure 9.8 shows a decision problem under uncertainty.

When applying the minimax rule, the actor will choose Option 3 and refrain from expanding the business. This is because both expansion options lead to negative free cash flows in a bad economic situation. In the case of a decision based on the maximax rule, the actor chooses Option 1, which promises the highest free cash flow in a good economic situation. If the maxim of equal probability is applied, the result is Option 2, which has the highest average value of 4.5 million EUR.

The application of the maxim of the optimism–pessimism index begins with the determination of the index value. If the actor selects an index value of 1/3, he weighs the best single consequence only half as important as the worst single consequence. This signifies that the actor is risk-averse. In this case, the overall consequences are

Criteria (C) and scenarios (S) / Options (O)	**C: Discounted free cash flow in millions EUR**	
	S_1: Good economic situation	**S_2: Bad economic situation**
O_1: Buy manufacturer with production plants in Germany and Poland	c_{11} = 16	c_{12} = -8,5
O_2: Create sales agencies in Germany and Poland	c_{21} = 10	c_{22} = -1
O_3: No business expansion	c_{31} = 0	c_{32} = 0

c = single consequence

Fig. 9.8 Decision problem under uncertainty

EUR −0.3 million for Option 1, EUR 2.6 million for Option 2, and EUR 0 million for Option 3. Option 2 is therefore chosen by a clear difference.

If applying the minimax-risk maxim, the regrets in the two scenarios must first be calculated. If the economic situation is good, the regret is EUR 0 million for Option 1, EUR 6 million for Option 2, and EUR 16 million for Option 3. If the economic situation is bad, the regret is EUR 8.5 million for Option 1, EUR 1 million for Option 2, and EUR 0 million for Option 3. Then, the maximal regrets of the three options are identified: EUR 8.5 million for Option 1, EUR 6 million for Option 2, and EUR 16 million for Option 3. Finally, Option 2 is chosen for its lowest maximal regret.

9.4.5 Decision Maxims to Overcome Multivalence

To overcome multivalence, the maxim of utility is of paramount importance. However, it is complex. Therefore, simpler scoring models are often used.

The application of the utility maxim (see Bamberg and Coenenberg 2002, pp. 47 ff.; Eisenführ and Weber 2003, pp. 115 ff.; Rommelfanger and Eickemeier 2002, pp. 140 ff.) comprises three steps:

- First, the single consequences must be transformed into utility values. This is done in parallel for each type of consequence. To avoid indirect weighting of the single consequences, the same sum of utility values must be assigned to each consequence type. The sum of "1" is recommended. The utility values of the options are thus between 0 and 1 for each type of consequence. It is also recommended to assign the highest utility value to the most favorable consequence and the lowest utility value to the least favorable consequence. When considering the purchase price of a machine, for example, the machine with the lowest price would receive the highest utility value.
- The second task is to assign weights to each consequence type. The weightings, based on subjective judgments, should reflect the relative importance of the criteria. "1" is suggested to be the sum of all weights.
- Once the consequence values have been transformed into utility values and the weights of the decision criteria, respectively consequence types, have been determined, the overall consequences can be calculated: the utility values are multiplied by their weights, and the weighted utility values are added.

Figure 9.9 shows a decision problem under multivalence.

Figure 9.10 summarizes the application of the utility maxim. The first line shows the utility values (u) corresponding to the single consequences. The transformation of the individual consequences into utility values is explained in Inset 9.1. The utility values are then multiplied by the weights (w) in the second line, and the weighted utility values are added together. As the figure shows, Option 2 has the highest sum and is therefore chosen. However, the sum of Option 1 is only 4% lower.

Criteria (C) and weights (W) / Options (O)	C_1: Discounted free cash flow in millions EUR	C_2: Creation of jobs in Poland (1)	C_3: Management capacity required (2)
	W_1: 0.7	W_2: 0.2	W_3: 0.1
O_1: Buy manufacturer with production plants in Germany and Poland	$c_{11} = 3.75$	c_{12} = many	c_{13} = high
O_2: Create sales agencies in Germany and Poland	$c_{21} = 4.5$	c_{22} = few	c_{23} = low
O_3: No business expansion	$c_{31} = 0$	c_{32} = none	c_{33} = none

c = single consequence
(1) = measured on an ordinal scale with the values "many", "some", "few" and "none"
(2) = measured on an ordinal scale with the values "high", "low" and "none"

Fig. 9.9 Decision problem under multivalence

Criteria (C) and weights (W) / Options (O)	C_1: Discounted free cash flow in millions EUR	C_2: Creation of jobs in Poland	C_3: Management capacity required	Sum of weighted utility values
	W_1: 0.7	W_2: 0.2	W_3: 0.1	-
O_1: Buy manufacturer with production plants in Germany and Poland	u_{11} = 0,45 w_{11} = 0,32	u_{12} = 0,57 w_{12} = 0,11	u_{13} = 0,17 w_{13} = 0,02	- $w_{1.}$ = 0,45
O_2: Create sales agencies in Germany and Poland	u_{21} = 0,55 w_{21} = 0,38	u_{22} = 0,29 w_{22} = 0,06	u_{23} = 0,33 w_{23} = 0,03	- $w_{2.}$ = 0,47
O_3: No business expansion	u_{31} = 0 w_{31} = 0	u_{32} = 0,14 w_{32} = 0,03	u_{33} = 0,50 w_{33} = 0,05	- $w_{3.}$ = 0,08

u = utility value
w = weighted utility value

Fig. 9.10 Result of applying the utility maxim

Inset 9.1 Transformation of Single Consequences into Utility Values

The single consequences are transformed into utility values for each type of consequence, respectively, decision criterion. Four different categories can be distinguished:

- Quantitative type of consequence where a high value is positive, such as discounted free cash flow
- Quantitative type of consequence where a high value is negative, such as costs
- Qualitative type of consequence where a high value is positive, such as job creation in Poland
- Qualitative type of consequence where a high value is negative, such as required management capacity

The transformation of each type of consequence or decision criterion into utility values is carried out in a way that the sum of the utility values is 1 to avoid implicit weighting. It is carried out as follows:

- For quantitative positive consequence types, the consequence values are transformed into utility values by expressing the consequence values as a proportion of the sum of all consequence values.
- For quantitative negative consequence types, the consequence values are transformed into utility values by first determining the reciprocal for each consequence value. The reciprocals are then expressed as a proportion of the sum of all reciprocals.
- For qualitative positive consequence types, the consequence values are first transformed into quantitative consequence values using a defined scale. Here, one should make sure that the transformation reflects the "distances" between the verbal consequence values as well as possible. Utility values can then be calculated in the same way as for quantitative positive consequence types.
- For qualitative negative consequence types, the consequence values are also first converted into quantitative consequence values using a defined scale. The negative consequence type is at the same time transformed into a positive consequence type by assigning the smallest quantitative value to the most disadvantageous verbal consequence values and the largest quantitative value to the most advantageous consequence value. Here too, the "distances" between the verbal consequence values should be reflected as well as possible. Utility values can afterwards be carried out in the same way as for quantitative positive consequence types.

In the case of quantitative consequence types, the consequence values may extend from negative values through zero to positive values. This is possible,

(continued)

Inset 9.1 (continued)
for example, with a consequence type such as profitability. In this case, the proposed conversion into utility values is impossible. Therefore, the consequence values must be transformed into a value area ≥ 0 before they are converted into utility values. This is possible by adding a constant to all consequence values. This increase of the consequence values by a constant amount is technically unproblematic because the utility values, independently of this operation, represent in any case only an interval scale.

The application of the utility maxim is complex. It is therefore relatively rarely used in practice. Often, it is replaced by one of the much simpler scoring models in which the single consequences are replaced by scores. Different approaches are used to achieve this task. Two frequently used rules are briefly explained below:

- A certain number of scores are available for each type of consequence. These are to be distributed as well as possible among the options according to their consequences.
- An ordinal scale is defined. The single consequences of the options are replaced by values from this scale. It is advisable to complete the task for one type of consequence after the other. This makes it easier to ensure that the replacement of the single consequences with scores is done properly.

The scores are then multiplied by the weights of the consequence types or decision criteria, as in the utility maxim, and added to the total consequences of the options.

Figure 9.11 shows the application of the second approach to the decision problem of Fig. 9.9. The single consequences are replaced by scores based on a scale ranging from "1 = sufficient" to "4 = very good."

The great advantage of simplicity is offset by the disadvantage of subjectivity. Should a discounted free cash flow of EUR 4.5 million be attributed 4 scores, or are 3 scores more appropriate, or should only 2 scores be assigned? There is no objective way to answer this question.

9.4.6 Combined Application of Decision Maxims to Overcome Risk or Uncertainty and Multivalence

If uncertainty and multivalence or risk and multivalence are simultaneously present, two decision maxims must be applied to determine the overall consequences. The uncertainty or the risk must be overcome first, followed by multivalence.

Figure 9.12 shows a decision problem under uncertainty and multivalence. If, for example, the maxim of the expected value is used to overcome the uncertainty

Criteria (C) and weights (W) / Options (O)	C_1: Discounted free cash flow in millions EUR	C_2: Creation of jobs in Poland	C_3: Management capacity required	Sum of weighted utility values
	W_1: 0,7	W_2: 0,2	W_3: 0,1	-
O_1: Buy manufacturer with production plants in Germany and Poland	p_{11} = 3 w_{11} = 2,1	p_{12} = 4 w_{12} = 0,8	p_{13} = 1 w_{13} = 0,1	- $w_{1.}$ = 3,0
O_2: Create sales agencies in Germany and Poland	p_{21} = 4 w_{21} = 2,8	p_{22} = 2 w_{22} = 0,4	p_{23} = 2 w_{23} = 0,2	- $w_{2.}$ = 3,4
O_3: No business expansion	p_{31} = 1 w_{31} = 0,7	p_{32} = 1 w_{32} = 0,2	p_{33} = 4 w_{33} = 0,4	- $w_{3.}$ = 1,3

p = score
w = weighted score

Fig. 9.11 Result of applying a scoring model

Criteria (C), weights (W), scenarios (S) and probabilities (P) / Options (O)	C_1: Discounted free cash flow in millions EUR		C_2: Creation of jobs in Poland (1)	C_3: Management capacity required (2)
	W_1: 0.7		W_2: 0.2	W_3: 0.1
	S_1: Good economic situation	S_2: Bad economic situation	-	-
	P_1: 0.6	P_2: 0.4	-	-
O_1: Buy manufacturer with production plants in Germany and Poland	c_{111} = 16	c_{112} = -8.5	c_{12} = many	c_{13} = high
O_2: Create sales agencies in Germany and Poland	c_{211} = 10	c_{212} = -1	c_{22} = few	c_{23} = low
O_3: No business expansion	c_{311} = 0	c_{312} = 0	c_{32} = none	c_{33} = none

c = single consequence
(1) = measured on an ordinal scale with the values "many", "some", "few" and "none"
(2) = measured on an ordinal scale with the values "high", "low" and "none"

Fig. 9.12 Decision problem under uncertainty and multivalence regarding the discounted free cash flow, values of EUR 3.75 million, EUR 4.5 million, and EUR 0 million result for the three options. The decision problem thus corresponds to the decision problem in Fig. 9.9 under certainty and multivalence. As shown in Subsection 9.4.4, the overall consequences of the three options can now be determined, for example, using the utility maxim.

9.5 Possibly: Determining the Crucial Strengths and Weaknesses of the Options

If the actor opts for a summary approach in Substep 7.2, the crucial strengths and weaknesses of the options must be determined in Substep 7.3. This may involve different points. For example, one option may have internal acceptance as a main strength, while another may increase the ability to enter emerging markets.

Regarding the decision problem summarized in Fig. 9.12, it could be argued, for example, that the discounted free cash flow of EUR −8.5 million would jeopardize the financial stability of the company in the case of a bad economic situation. Accordingly, Option 1 cannot be chosen, even though it would produce by far the best financial result in a good economic situation and would also create many jobs in Poland. On the other hand, the free cash flow of Option 2 of EUR −1 million is acceptable in the case of a bad economic situation. It is chosen in view of the EUR 10 million free cash flow in a good economic situation and the creation of jobs in Poland.

9.6 Making the Decision

Finally, in Substep 7.4, a decision must be made and an option selected. If the actor is not convinced of any option and believes that a better solution can be found, he may also decide to develop other options. This corresponds to a heuristic loop returning to Step 3 according to the principle of generate-and-test (see Inset 6.1). However, postponing the decision and continuing the problem-solving process should remain the exception. If the problem-solving process is carried out with the necessary thoroughness, the probability of finding a significantly better option through a heuristic loop is low. Frequent postponement of the decision demonstrates a lack of courage rather than thoroughness.

From a practical point of view, it is crucial that the problem-solving process ends with a clear decision. It is important for those involved in the problem-solving process and those affected by the decision to know whether a decision has been made and, if so, which option has been chosen.

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Part III

Special Problems and Approaches to Solve Them

10 Decision Sequences

10.1 Distinction between Decision Sequences and Decision Problems with Subproblems in Succession

In Part II, a general heuristic problem-solving procedure was introduced and explained in detail. As shown, complex problems often have multiple causes. This often results in multiple subproblems in the problem analysis, which must be solved in parallel or in succession. For example, unsatisfactory performance among sales staff can be traced back to both unclear setting of sales objectives and a reward system with insufficient performance incentives. Since effective incentives can only be determined once the objectives are clear, the sales objectives subproblem must be resolved before the sales staff remuneration subproblem. The actor thus deals with two subproblems to solve in succession. However, once the first subproblem is solved, the actor can tackle the second subproblem without delay. This means that the overall problem can be solved relatively quickly.

This chapter is not concerned with a decision problem with subproblems that are to be solved in succession. A decision sequence in this chapter signifies that one, several, or all the options under discussion today will lead at a future time, for example, in some years, to further decisions that can already be foreseen today. To be able to choose the right option in the current decision problem, the actor must take into account these future decisions with their options and their consequences. Of course, this is only possible to the extent that these future decisions with their options and consequences are known today.

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10.2 Visualizing Decision Sequences with the Help of Decision Trees

In Part II, decision problems were summarized with the help of decision matrices. This form is not suitable for decision sequences with decisions made at different points in time. To be able to clearly display the various interrelated decisions and their options and consequences, it is useful to create a decision tree.

A decision tree

- Is a graphical representation
- Showing interrelated decisions on at least two levels
- With their options and possibly their consequences
- In decisions under risk and uncertainty, the decision tree also contains at least one additional level with scenarios (see Bamberg 1993, pp. 886 ff.)

Figure 10.1 presents two decision trees. The first decision tree represents a decision sequence under certainty with decisions at two levels. The second tree shows a decision sequence under uncertainty with two levels of decisions and an additional level with scenarios. When examining these two trees, two points must be noted:

- A decision option selected today may not incur the necessity of other decisions at later points of time or enable such decisions. In each of these two decision trees, this is the case for Option 1. This situation is also present in the second decision tree if Option 3 is selected and scenario 2 occurs.
- In a decision tree for a problem under uncertainty, the scenarios may only be important for individual options. This means that, for some options, the consequences can be predicted with certainty. (This is also true for a decision tree for a problem under risk.) This is the case for Option 1 in the second tree. It leads to no further decision and can also be assessed independently from the two scenarios.

10.3 Choosing the Best Option in a Decision Sequence

As Sect. 10.1 shows, a decision sequence links decisions to clearly different points in time. The decision problem at the present includes options, which later lead to decisions that can already be foreseen today. However, this link between decisions dispersed in time does not mean that all these decisions must be made immediately. Since the options and/or the consequences of the pending decisions can still change over time, it would not be rational to make a decision now. Only the current decision should be made in the present. When judging the options available for the present decision, the options and consequences resulting from future decisions must, however, be taken into account. If this is not done, future opportunities and threats, and therefore possibly essential effects of the options discussed at present, are not included in the present decision.

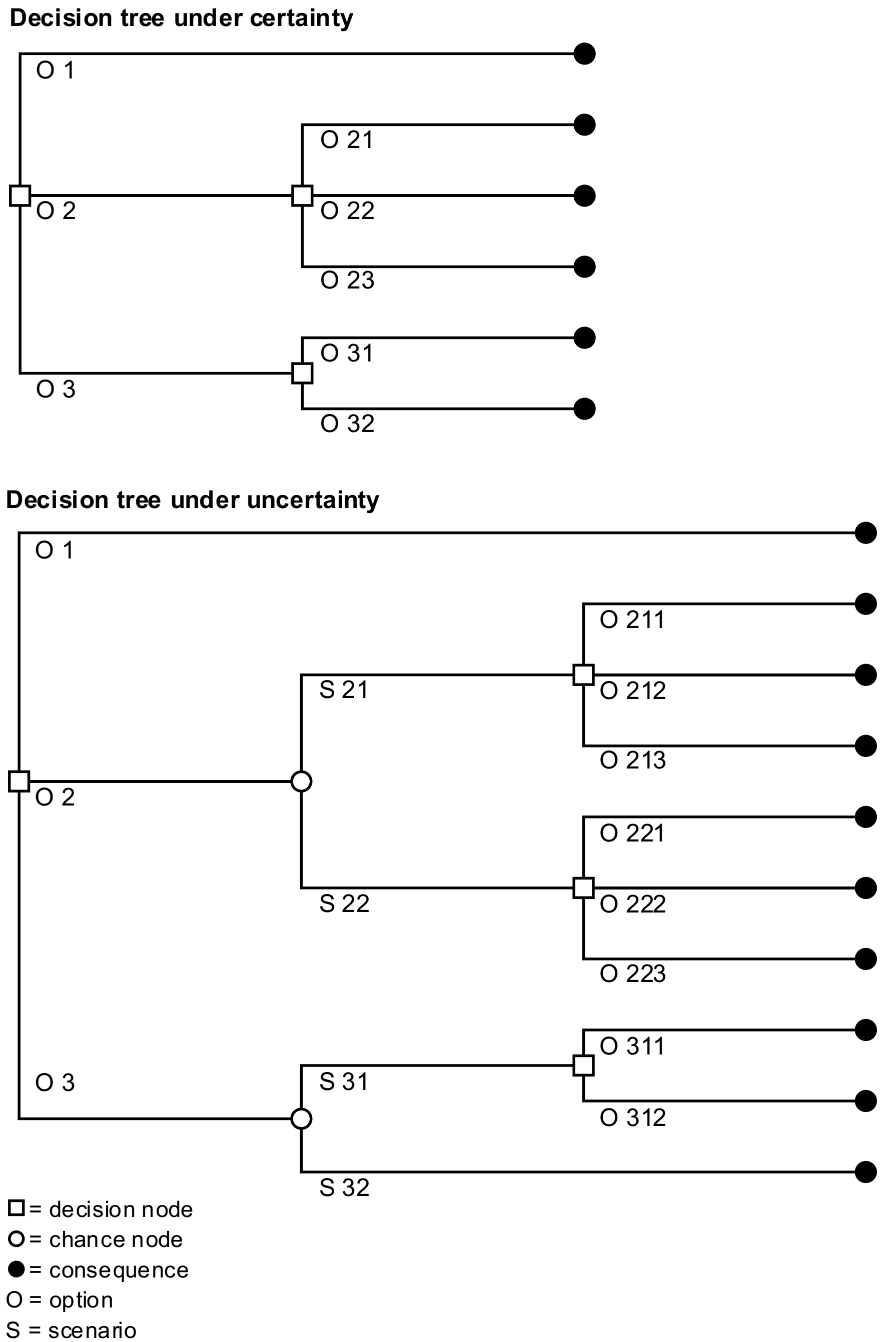

Fig. 10.1 Two examples of decision trees

The selection of the optimal solution can—similar to Step 7 in the general heuristic problem-solving procedure—take place summarily or analytically.

If proceeding summarily, the actor studies the decision tree. Based on the tree, he assesses the present options and decides. As decision trees provide a clear overview of complex decision sequences, the summary approach seems to be suitable.

The analytical approach determines the overall consequences of the options. The determination of the overall consequences is done using the so-called roll-back method (see Bamberg 1993, pp. 891 ff.):

1. If the decision problem is multivalent, it must be overcome directly at the ends of the tree. To do so, a decision maxim to overcome multivalence must be applied (see Subsection 9.4.5).
2. Afterwards, the consequences must be summarized, beginning at the ends of the tree on the right and moving toward the root on the left.

   2.1 At the decision nodes, the option with the better consequences should be chosen in each case.

   2.2 At the chance nodes, a consequence value must be calculated or selected. For this, a decision maxim to overcome risk or to overcome uncertainty must be applied (see Subsections 9.4.3 and 9.4.4).

The roll-back procedure will now be explained with the help of an example: Fig. 10.2 shows the decision tree under uncertainty previously presented in Fig. 10.1. However, the consequences expressed as discounted cash flows are now shown at the ends of the tree. As no other consequences appear, it is a univalent decision problem:

- First, the best option is identified for each of the decision nodes on the right. They are options O 211: EUR 2 million, O 221: EUR 1 million, and O 311: EUR 5 million.
- Next, the consequence values are calculated for each of the two chance nodes in the middle. If, for example, the decision maxim of equal probability is used, it would yield EUR 1.5 million for the upper chance node and EUR 2 million for the lower one. (If the minimax maxim is used, these values would be EUR 1 million and EUR −1 million, respectively.)
- Next, a choice can be made between the three options of the decision node on the left. From the options O 1: EUR 0.5 million, O 2: EUR 1.5 million, and O 3: EUR 2 million, the actor chooses O 3. In doing so, the actor takes a considerable risk. Depending on which scenario occurs, S 31 or S 32, the discounted cash flow will be EUR 5 million or EUR −1 million. (A risk-averse actor would use the minimax maxim. He would then choose between O 1: EUR 0.5 million, O 2: EUR 1 million, and O 3: EUR −1 million. In this case, he would choose O 2.)

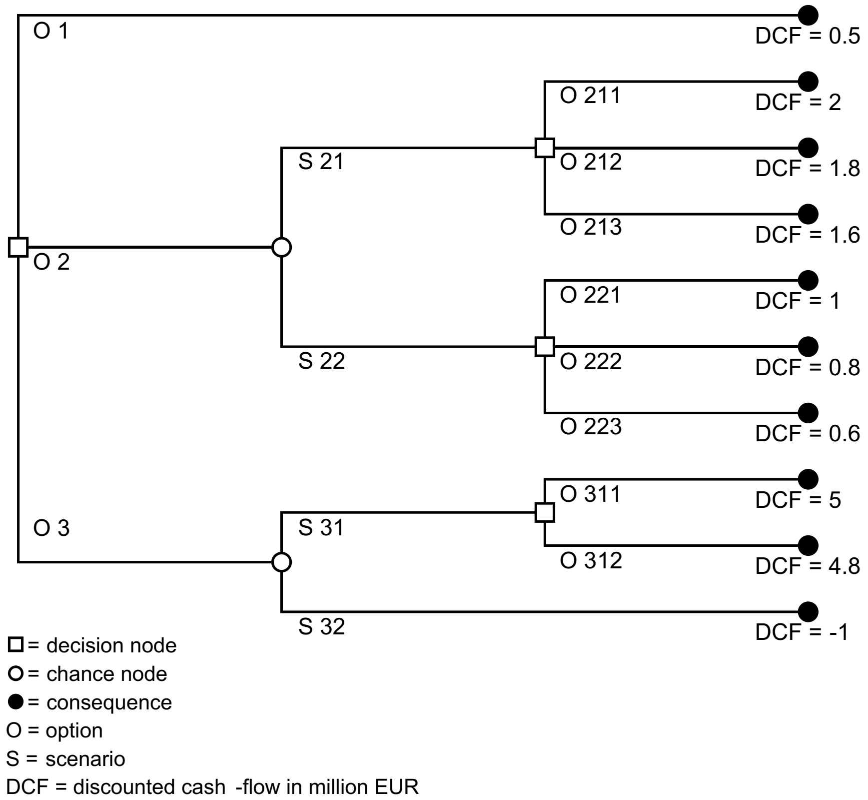

Fig. 10.2 Decision tree as a starting point

Reference

Bamberg G (1993) Entscheidungsbaumverfahren. In: Wittman W, Kern W, Köhler R et al (eds) Handwörterbuch der Betriebswirtschaft, Teilband 1, 5th edn. Schäffer-Poeschel, Stuttgart, pp 886–896

11 Information Procurement Decisions

11.1 Information Procurement Decisions as Decisions at the Meta-Level

When tackling a decision problem, the actor always must work with problems on two levels:

- On the one hand, he must deal with the discovered problem itself: understand it, identify solution options, assess these, and finally make a decision.
- On the other hand, there are several tasks at the meta-level: problem-solving must be planned, people need to be integrated into the work on problem-solving, and other persons must be informed about the progress made. A further task at the meta-level, with which the actor must deal, is to decide whether to proceed based on existing information or whether the level of information should first be improved.

Already in problem analysis, new information may be gathered from internal or external sources in various degrees of detail and reliability. In the step of developing options, further information can also be obtained. However, the pivotal meta-decision for procurement or no procurement of additional information occurs when evaluating the options: should the decision be based on the present consequences, or should additional resources be invested?

The more is invested in information procurement, the greater the probability that good problem-solving options will be found and the best one will be selected. However, the procurement of additional information also involves additional costs. Moreover, it prolongs the problem-solving process and thereby delays the decision.

Deciding whether to obtain additional information is simple in principle: obtaining new information always makes sense if the additional benefits outweigh the costs. If this is not the case, one should not collect additional information. Such a general recommendation is, however, of very little use to the actor in a concrete

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case. The best-known approach for making decisions on the procurement of additional information was developed by Bayes. It is presented in Sect. 11.2. It is an analytical approach that is based on several, partly restrictive assumptions. Bayes' approach is therefore often not applicable. For this reason, the authors then present in Sect. 11.3 a heuristic approach.

11.2 Bayes' Analytical Approach for Deciding on Additional Information

As mentioned above, Bayes bases his approach on assumptions, some of which are highly restrictive. They are summarized in the following points:

1. A first restriction is that Bayes' principles refer to decision problems under univalence and risk (see Weibel 1978, p. 11). In other words, Bayes assumes that the actor only must deal with a single decision criterion and will be confronted with several environmental scenarios for which he knows the probabilities of occurrence.
2. Moreover, Bayes assumes that the actor knows the options, the environmental scenarios with their probabilities of occurrence, and the consequence values. He would therefore be able to make the decision. The approach of Bayes answers the question of whether the actor should decide based on the present decision matrix or whether he should postpone the decision and improve the quality of the decision through the procurement of additional information. With this exclusive focus, Bayes ignores the question of additional information in the problem analysis step and in the development of options step.
3. Bayes' consideration of the procurement of additional information addresses only the probabilities of occurrence for the different scenarios. However, the additional investment in information does not produce more precise consequence values (see von Nitzsch 2002, pp. 220 ff.).
4. The fourth premise concerns the decision maxim applied by the actor. Bayes assumes that the actor uses the expectation value maxim to aggregate the consequence values to the overall consequences of the options (see Weibel 1978, p. 20). However, as shown in Chap. 9, the use of this maxim can be problematic.
5. Another assumption is that only problems with the two options "do something" and "do nothing" are considered (see Weibel 1978, p. 21).
6. Finally, Bayes does not include the dimension of time in his considerations. He thereby excludes the important practical question of the effects of postponing the decision.

The approach used by Bayes to resolve the information procurement question consists of calculating the expectation value with information procurement and comparing it with the previously determined expectation value of the best option without information procurement. The calculation of the expectation value with information procurement is now explained based on an example from von Nitzsch (2002, pp. 220 ff.). In the presentation below, the special terminology introduced by

Options \ Criteria, scenarios and probabilities	Profit in millions of EURO	
	Launch successful	**Launch unsuccessful**
	Probability 0.6	**Probability 0.4**
Product launch	+ 200	- 50
No product launch	0	0

Fig. 11.1 Decision matrix as a starting point

Bayes and adopted by von Nitzsch has been avoided. To improve the readability of the text, the number of symbols has also been kept to a minimum.

In the example, a company is faced with a decision about whether to launch a new product. Figure 11.1 shows the decision matrix of the actor.

If the maxim of expectation value is used, then the product should clearly be launched: the expectation value amounts to EUR 100 million, against an expectation value of zero if the company decides not to introduce the product.

Launching the product may incur a loss of EUR 50 million with a probability of 0.4. The actor therefore takes a significant risk if he decides on this option. This may induce him to obtain additional information to reduce the risk. In the example, the actor has the possibility of commissioning a study at a cost of EUR 2 million. This study will either support or oppose the introduction of the product. The actor also has information regarding the accuracy of such a study (see von Nitzsch 2002, p. 220):

- A successful product launch can be predicted with a 90% probability. For only 10% of successful launches, the study will oppose the launch.
- An unsuccessful product launch can be predicted with an even greater probability of 95%. For only 5% of unsuccessful launches, the study will support the launch.

In this case, the actor now has three options:

(1) He can decide to launch the product.
(2) He can decide not to launch the product.
(3) He can postpone the decision and first commission the study.

If he chooses option (3), he will—after the study has been completed and therefore based on a better level of information—choose between options (1) and (2).

Figure 11.2 shows the decision tree for the problem. The figure not only gives an overview of the problem structure but also presents both the existing and the still

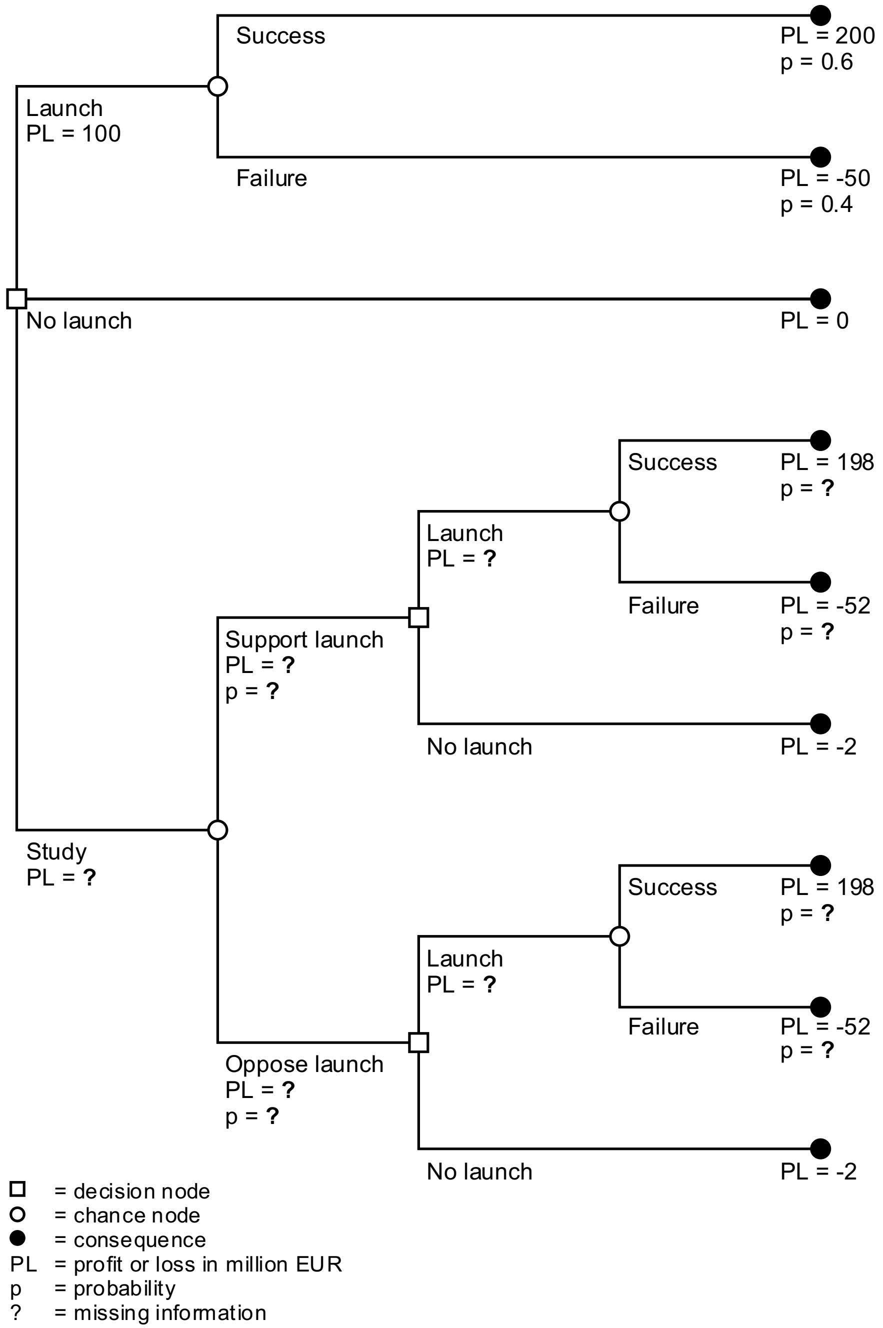

Fig. 11.2 Decision tree with missing information (adapted from von Nitzsch 2002, p. 221)

Product launch / Market study	**Success**	**Failure**	**Probabilities of supporting and opposing the launch**
Support the launch	0.9 • 0.6 = 0.54	0.02	**0.56**
Oppose the launch	0.06	0.95 • 0.4 = 0.38	**0.44**
Probability of success and failure	0.6	0.4	1

Fig. 11.3 Probabilities of supporting and opposing the product launch (adapted from von Nitzsch 2002, p. 222)

missing information. As the decision tree shows, the expectation value of the study, which is required for the decision, is missing. It can only be calculated if the missing probabilities can be determined.

The probabilities that the market study will support or oppose the introduction of the product can now be determined as follows:

- The actor knows that the probability of a successful product launch is 0.6 and the probability of a failed one is 0.4.
- Furthermore, the actor knows that the study can predict a successful product launch with a probability of 0.9 and a failed one with a probability of 0.95.
- These two pieces of information are now brought together. As Fig. 11.3 shows, the probability that the study will support the product launch is 0.56, and the probability that it will oppose it is 0.44.

To be able to calculate the expectation value of the study, four more probabilities are needed (see von Nitzsch 2002, p. 222):

- Probability of a successful product launch if the study supports the launch: 0.54 ÷ 0.56 = 0.964.
- Probability of a failed product launch if the study supports the launch: 0.02 ÷ 0.56 = 0.036.
- Probability of a successful product launch if the study opposes the launch: 0.06 ÷ 0.44 = 0.136.
- Probability of a failed product launch if the study opposes the launch: 0.38 ÷ 0.44 = 0.864.

The decision tree can now be worked through from right to left. As Fig. 11.4 shows, the study has, with EUR 105 million, a higher expectation value than the

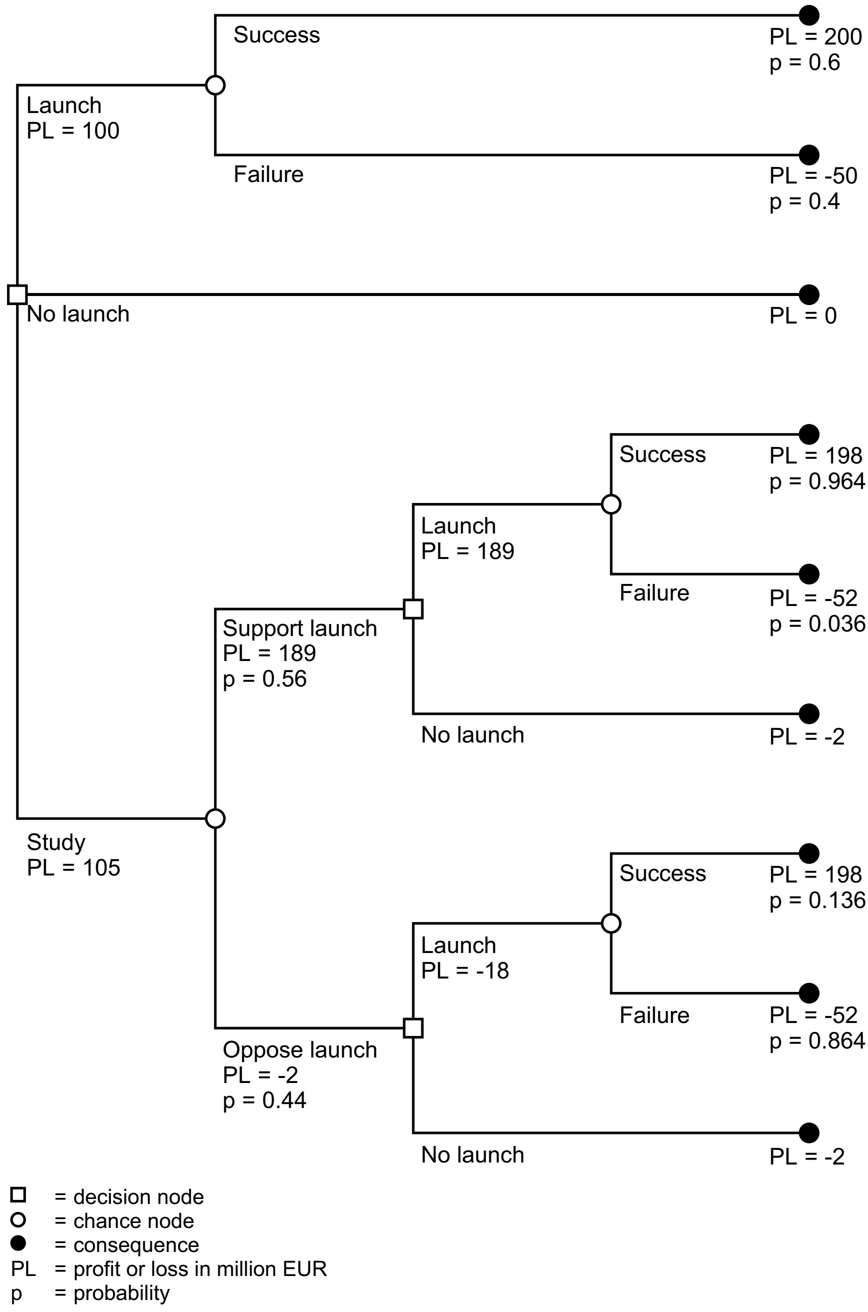

Fig. 11.4 Complete decision tree (adapted from von Nitzsch 2002, p. 223)

product launch without the previous study. It is therefore worthwhile for the actor to invest EUR 2 million in the study and to make the decision about the product launch based on the study's result (see von Nitzsch 2002, p. 223).

11.3 Heuristic Approach for Deciding on Additional Information

As Fig. 11.5 shows, the heuristic approach for making information procurement decisions consists of four steps. They are briefly described below.

The detailed consideration of costs and benefits of the procurement of additional information appears only to be worthwhile if the actor can specify a procedure for the information procurement and if the time frame allows such measures. For this reason, it is worth first making a rough assessment of the "feasibility" of information procurement in Step 1:

- For this purpose, the information required must first be specified. There is, for example, the need to determine the effects of price changes on demand.
- Based on this rough specification of information needs, the actor must then consider the time needed. The time spent on information procurement plays an especially important role in two situations: on the one hand, it is especially important when a decision is required by outside circumstances. This is normally the case, for example, with decisions about acquisitions. Time for the procurement of information is, on the other hand, important when a threat problem seems to be

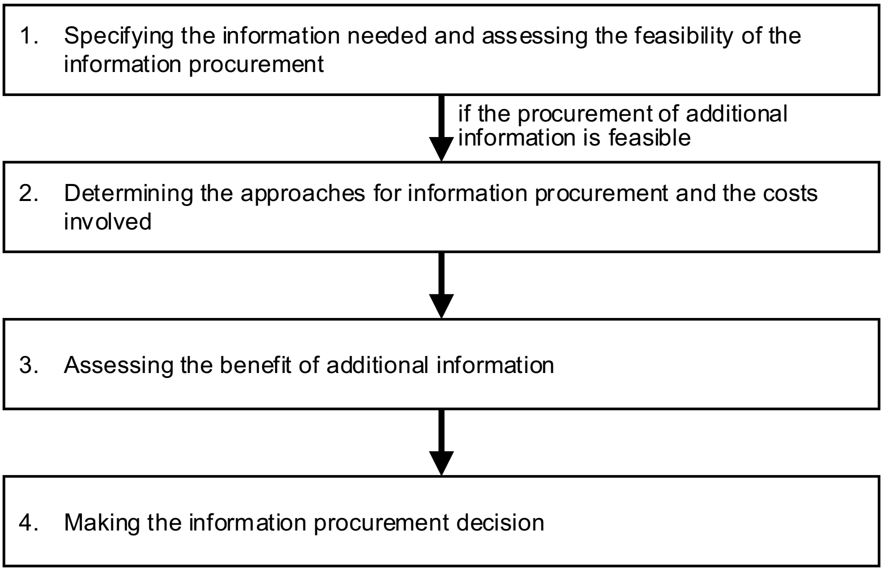

Fig. 11.5 Heuristic procedure for deciding on additional information

escalating and therefore should be tackled quickly. This could be, for example, a quality defect in a mass consumer item that is already being sold. Information procurement may in such cases not always be feasible in time.

Where measures for the procurement of additional information appear feasible, Step 2 is to determine the approaches to obtain the information and the corresponding costs. Sometimes the needed information must first be specified. This is because the types of data are often relevant for the selection of the procurement approach and the costs.

The assessment of the benefits of additional information in Step 3 essentially depends on the following points:

- The significance of a wrong decision.
- The improvement in the quality of the decision resulting from the additional information.

It is usually possible to determine approximately the effects of a wrong decision. One can get a good idea of this by asking whether the difference between a good and a bad problem solution lies in 10,000, in 100,000, or in millions of euros. However, it is generally very difficult to assess how far the additional information will improve the quality of the decision. The actor should nonetheless be able to roughly estimate whether the additional information will allow a significant improvement in the understanding of the problem. It is only worthwhile to pursue the idea of obtaining additional information if there is a significant improvement.

To make the final decision in Step 4, the costs and benefits of additional information must be weighed. As shown, the benefits of the information can usually only be determined as an "order of magnitude." They are compared with the costs of additional information, which can usually be estimated quite accurately. In general, one will decide in favor of additional information if the financial consequences of a wrong decision clearly exceed the costs of information procurement.

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Collective Decisions 12

12.1 Collective Decisions and Their Importance in Business

A variety of different phenomena can be found under the heading of collective decisions. Following Brauchlin (1990, pp. 250 ff.) and von Nitzsch (2002, p. 61), collective decisions can be classified into categories according to three criteria. Figure 12.1 shows this morphology of collective decisions. As the figure also shows, collective decisions in companies have three characteristics:

- Collective decisions in companies involve groups of between three and around 20 people.
- The groups are formally established collectives with a clear assignment of tasks, competencies, and responsibilities. The range of such groups is very wide: it includes boards of directors, top management teams, divisional management teams, project steering groups, and special committees.
- The goal systems of the group members are aligned regarding the essential points. However, it would not be realistic to imagine that all group members have an identical understanding of the goals.

In recent decades, a greater tendency toward collective decisions has been observed in the business world. Various causes have led to this development:

- The tendency toward consolidation leads to fewer businesses that are owned by an individual and in which one individual then has the final say. If there are several important owners, they will usually be represented on the board and be involved in important decisions. In the case of a public company, the General

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<table>
<tr><th>Dimensions</th><th colspan="12">Possibilities</th></tr>
<tr><td>Number of people involved</td><td colspan="4">Dyade; 2 persons</td><td colspan="4">Group; 3 to approx. 20 persons</td><td colspan="4">Organized systems; approx. 20 to several millions of people</td></tr>
<tr><td>Type of group</td><td colspan="6">Formal collective</td><td colspan="6">Informal collective</td></tr>
<tr><td>Goals</td><td colspan="3">Totally congruent</td><td colspan="3">Congruent in essential points</td><td colspan="3">Divergent in essential points</td><td colspan="3">Totally divergent</td></tr>
</table>

[shaded box] important for collective decisions in the sense of this chapter

Fig. 12.1 Dimensions of collective decisions and their possibilities (adapted from Brauchlin 1990, pp. 250 ff. and von Nitzsch 2002, p. 61)

Assembly normally elects a board that represents not only the owners but also other stakeholders of the company.

- There is a general increasing desire to offer a greater number of people the opportunity to take part in decision-making (see Brauchlin 1990, p. 154). This desire is an expression of the political ideals of democracy.
- The desire for an individual to be involved in the decision is a question of personal prestige. Participation in decision-making also offers employees the opportunity to advance their own interests (see Brauchlin 1990, p. 254).
- The increasing popularity of collective decision-making in business is frequently justified by arguing that it leads to better decisions. Whether this is true is debatable. Committee-based decision-making does not only have advantages in comparison to individual decision-making; there are also several serious disadvantages.

12.2 Special Characteristics of Collective Decisions

12.2.1 Different Goals and Situation Assessments of the Group Members

Collective decisions are more challenging than individual decisions. It is because the individual members of the collective usually pursue different goals and assess features of the decision situation differently (see Eisenhardt and Zbaracki 1992, p. 27).

From the authors' point of view, the differences in the goals pursued have the following reasons:

- Not all members of the group need to pursue all the group's goals.
- The understandings of the concrete content of a goal are not completely congruent.
- There are differences in the weighting of the pursued goals.

The differences in the assessment of the decision situation between the group members concern, from the authors' point of view, mainly two features. On the one hand, there are different opinions about the environmental scenarios and their probabilities of occurrence. On the other hand, the members of the decision group take different solution options into account.

12.2.2 Differences in Decision-Making between Groups and Individuals

When groups are entrusted with decisions, the decision behavior is different from what is seen with individuals. Group decisions are a complex phenomenon, and empirical research concentrates on individual questions, so it is difficult to give an overview of the effects of collective decisions. Figure 12.2 nonetheless attempts to give such an overview. The authors are, however, conscious that the figure is incomplete and that the different cause-effect relationships depicted here remain somewhat controversial.

It is known from research that members of a group strive for conformity. To this end, group members are ready to adjust their values and objectives. If harmony in the group appears extremely important to a group member, he may even, more or less consciously, ignore or misrepresent facts. Inset 12.1 presents an experiment carried out by Asch, which confirms the surprising finding that not just values and goals, but even facts, may be sacrificed for group conformity (see von Nitzsch 2002, p. 63).

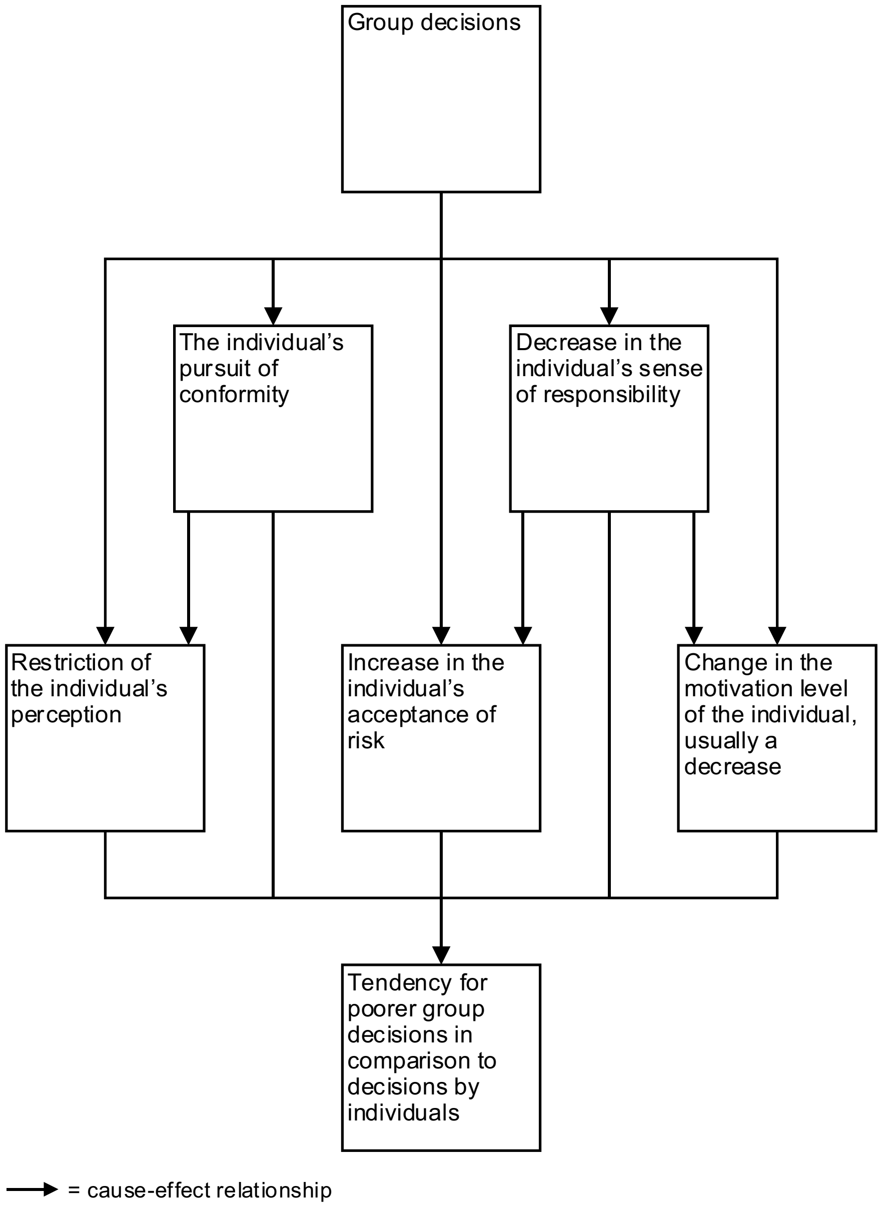

Fig. 12.2 Tendency toward poorer decisions by a group compared to an individual

Inset 12.1 Asch's Experiment on group members' pursuit of conformity (Text based on von Nitzsch 2002, pp. 63 ff.)

In Asch's experiment (1955, pp. 31 ff.), subjects had to compare the length of a given line with the length of three reference lines and declare which of them it matched. Since these three reference lines clearly differed in length, the task was easy to solve and yielded an error rate of just 0.7% in individual tests.

Afterwards, the subjects were put into groups of seven people. The subjects occupied the sixth position. The other six group members were accomplices of the investigators. The estimates of the group members were communicated openly. After six rounds during which the accomplices of the investigators always gave the right answer, 12 further rounds followed in which they all named the same wrong reference line. Although the task was just as easy to solve in the group as individually, the rate of incorrect answers by the subjects climbed to 37%, and 75% of the subjects made a mistake at least once.

The pursuit of conformity usually only involves statements and behavior, but not values and thoughts. In this case, one speaks of compliance. It is, however, possible in the longer term that the group will even modify values and thinking, resulting in acceptance of the group norms by its individual members (see von Nitzsch 2002, pp. 63 ff.).

Membership in a group leads not only to the desire for homogeneity but also brings about changes in the individual group member's sense of responsibility. The individual can hide behind the group, as the group situation leads to diffuse responsibilities (see Brauchlin 1990, p. 261).

A third effect of being in a group is the restriction of the group members in the perception of the decision situation. This phenomenon—fatal for decision-making—has three fundamental causes (see von Nitzsch 2002, pp. 75 ff.):

- The need for conformity can lead to neglecting uncomfortable facts. The fact that negative elements may be missing from the picture is especially worrying, as these would often significantly influence the decision.
- The pursuit of conformity also means that agreeing votes prevail in group discussions. This gives the group members too much self-confidence. The individual assumes that many people cannot be mistaken (see von Nitzsch 2002, p. 75).
- Finally, group members are inclined to value statements from group members more than those from people outside the group. This in-group bias automatically prevents the perception of dissenting views, which do not conform to those of the group (see von Nitzsch 2002, p. 75).

A fourth consequence of group decisions is a higher readiness to accept risk. This risk-shift effect is, on the one hand, the result of a lower sense of responsibility of the individuals. On the other hand, people with a higher risk acceptance normally have greater weight in the discussion than group members who are risk-shy (see Brauchlin 1990, p. 261; von Nitzsch 2002, p. 75).

Finally, the group influences the motivation of the group members (see von Nitzsch 2002, pp. 67 ff.):

- High group cohesion can work to encourage and increase the motivation of the individuals.
- The opposite is more frequent, however: unconsciously or consciously, motivation is reduced by membership in the group. Collective responsibility means that group members unconsciously reduce their involvement. This phenomenon is named "social loafing." Group members can even behave as free riders, letting the others take on the work. This behavior may reduce the motivation of the other group members and lead them to reduce their efforts in order not to feel exploited. This phenomenon is called the sucker effect.

The collapse of Swissair, the former Swiss national carrier, provides an interesting example of group decision behavior. Subsequent analysis showed that the decision-making behavior of the board played an essential role in the downfall of the company:

- Asking awkward questions or expressing divergent opinions was evidently frowned upon and therefore happened only rarely.
- Several board members failed to attend meetings or left early when important decisions were made, such as the purchase of LTU. This shows that individual board members did not feel full personal responsibility for decisions.
- The investigating authorities found that on several occasions, decisions involving acquisitions were made without sufficient information about the accompanying liabilities. Furthermore, the board was also not adequately informed about the effective return flow from the acquisitions in comparison to the planned figures.
- In retrospect, it is obvious that the hunter strategy pursued by Swissair was a high-risk strategy. It seems possible that the comparatively high-risk acceptance of the Swissair board could be attributed to the risk-shift effect typical of collective decision-making.
- The motivation and the involvement of the board members are difficult to judge in retrospect, but it is assumed that these varied greatly.

In conclusion, the difficult question arises regarding what can be done to limit the negative effects of group decisions as much as possible. The authors see two possible approaches:

- All the facts must be on the table. A culture that allows divergent views in a group must be developed. This can also be promoted by applying rules. For example, there could be a rule that all group members give their views on certain questions or name problems to be discussed before the meeting.

- The sense of responsibility of the individual group members should be strengthened as much as possible. This can be promoted by using the minutes to record individuals' votes. Another possibility is for the group to delegate certain decision problems to subgroups or even to individual group members.

12.3 Rules for Making Collective Decisions

12.3.1 The Importance of Rules for Making Collective Decisions

The following rules for making collective decisions only concern the final step in the decision-making process, in which the best option is chosen. Moreover, they are only applicable if the group did not reach a consensus in the earlier phases of the decision-making process. The group members' pursuit of conformity (see Subsection 12.2.2) normally leads to an agreement on an option while working on the decision problem, and a final vote is no longer necessary. In a minority of cases, however, the group members will have different preferences from the start or develop them during the common work on the problem. They form the basis for the following rules for making collective decisions. This section, therefore, concerns a problem that does not frequently occur in practice, but when it does, it has significant consequences. It is not only important that the group arrive at a clear and sound decision regarding the problem; the way in which the decision is made will also be important for the future working climate within the group.

12.3.2 The Preference Profile of the Group as Starting Point

The order of preference of a group member indicates how the options would be ranked if the person were deciding alone. If the group has two options, a and b, any given group member X may:

- Prefer a to b
- Prefer b to a
- Consider a and b to be equivalent

Group member X thus must choose between three possible orders of preference. But if three different options are open to the group, group member X must choose between 13 possible orders of preference (see Bamberg and Coenenberg 2002, pp. 25 ff.; Rommelfanger and Eickemeier 2002, pp. 192 f.).

If the decision committee is composed of three members, X, Y, and Z, and there are two options, then this means that 27 different decision constellations, or preference profiles, are possible:

- X, Y, and Z can prefer a to b
- X and Y can prefer a to b, while Z prefers b to a
- etc.

With three decision options, a, b, and c, and three group members, the number of possible preference profiles climbs to $133^3 = 2197$ (see Bamberg and Coenenberg 2002, p. 252; Rommelfanger and Eickemeier 2002, pp. 193 f.).

The starting point for any collective decision is the preference profile of the group. It summarizes the individual orders of preference of all group members. To reach a collective decision, one must produce the collective order of preference of the group out of the individual orders of preference or at least determine the best option from the group's point of view. In both cases, rules are needed. However, before looking at possible rules, the requirements that such rules must reasonably satisfy are defined.

12.3.3 Requirements on Rules for Forming a Collective Preference Order

Arrow defines four requirements on rules for forming a collective preference order (see Arrow 1963, pp. 22 ff., Bamberg and Coenenberg 2002, pp. 255 ff.; Rommelfanger and Eickemeier 2002, pp. 198 f.):

1. The rule system should be able to produce a collective order of preference for each possible preference profile. As shown, with a three-member group evaluating three options, there are 2197 possible preference profiles.
2. The second requirement is that if all group members rank option a above option b, then the collective order of preference must also rank a above b.
3. The third requirement of Arrow is that where two different preference profiles match regarding two options, a and b, the two collective orders of preference must also match in the order of a and b. This means that any other differences in the preference profiles will not influence the ranking of a and b in the two collective orders of preference. Inset 12.2 presents an example of this rather complicated requirement, known as the independence of irrelevant options.
4. Finally, the fourth requirement is that no group member has a special status. If, for example, each preference of member X automatically becomes a component of the collective order of preference, X would have a dictatorial position. Under these conditions, the preferences of the other group members would only play a role in relation to the options to which X would be indifferent.

If rules for forming a collective order of preference are expected to be reasonable and democratic, it seems plausible to require that all four requirements of Arrow should be met at the same time. However, supported by contributions from other researchers, Arrow has proved that such rules exist only for the special case of two options. The rules for this special case are, moreover, very simple; it is a majority decision (see Bamberg and Coenenberg 2002, pp. 257 f.).

Inset 12.2 The independence of irrelevant options as a requirement on rules for forming a collective order of preference (Text based on Bamberg and Coenenberg 2002, pp. 256 f.)

The requirement of the independence of irrelevant options means that if two preference profiles agree on the order of two options, the two collective orders of preference must also agree on the order of the two options. Differences in the two preference profiles concerning other options may not change this.

The following figure shows two preference profiles, each of which represents three persons faced with three options: a, b, and c. As the figure shows, the two preference profiles are in agreement as far as a and b are concerned: in each preference profile, two group members prefer a to b, while the third group member prefers b to a.

Preference profile / Individual preference orders	**Preference profile 1**			**Preference profile 2**		
	X	**Y**	**Z**	**U**	**V**	**W**
Preference 1	a	a	c	c	c	b
Preference 2	b	b	b	a	a	a
Preference 3	c	c	a	b	b	c

X, Y and Z = members of the first decision group
U, V and W = members of the second decision group
a, b and c = options

Preference profiles of two groups of three individuals concerning three options (adapted from Bamberg and Coenenberg 2002, p. 156)

Arrow's third requirement means that the rule system should produce, in both cases, a collective order of preference in which the relative positions of a and b are the same. Since two of the three group members prefer a to b in both preference profiles, the two collective orders of preference may also prefer a to b. But as the three group members are not united in reference to a and b, it is also possible that the collective orders of preference will show no preference between a and b.

With the requirement of the independence of irrelevant options, Arrow has eliminated the possibility that, for instance, in one collective order of preference a will be preferred to b, while in the other, the two options are viewed as equivalent.

12.3.4 Classic Rules for Forming a Collective Preference Order or for Determining the Preferred Option

As shown in the previous subsection, there are no rules that simultaneously fulfill all four requirements of Arrow for reasonable and democratic collective decisions. Nevertheless, many groups in companies have common tasks, competencies, and responsibilities and therefore must make collective decisions. The following rules allow a group to take a decision even though they do not meet all of Arrow's requirements. The rules can be classified according to whether they:

- Produce a collective order of preference for the options or
- Simply determine the group's preferred option

A simple method is the simple majority: each group member votes, and the option that gets the most votes is chosen. If two options share first position, the chairperson decides. Another rule for this case would be a second vote, which considers only the two options in the first position. If there is again a tie, the chairperson has the casting vote.

The simple majority method is easily understood and leads to a decision. Its disadvantage is that it only yields the one preferred option and says nothing about the order of preference of the remaining options. If the chosen option later proves impossible to implement, then the vote must take place again.

Naturally, it is also possible to insist on an absolute majority or even unanimity. The disadvantage of this is that often no decision can be made and the problem has to be adjourned. For this reason, it is unusual in companies to demand either an absolute majority of the votes or unanimity. To prevent chance decisions, however, a particular quorum can be required for votes.

Borda presents an alternative approach. His proposal is that each member of the group should allocate points to each option: the worst option receives one point, the second-worst two points, and so on. With five options, the preferred option will get five points. The collective order of preference can now be determined by adding the points for each option and sorting the options according to their scores (see Bamberg and Coenenberg 2002, pp. 263 f.; Rommelfanger and Eickemeier 2002, pp. 195 f.). This is a simple procedure that not only determines the preferred option but also yields an order of preference. This makes it somewhat surprising that it is not used in business more often.

Another method, frequently used in practice, is the comparison of pairs. It begins with the comparison of two options. The winning option is then compared to a third option, and so on. The option that wins in the final comparison is chosen (see Bamberg and Coenenberg 2002, pp. 265 f.; Rommelfanger and Eickemeier 2002, p. 196).

If there is one option that a majority of the decision group considers better than all the others, then this will always win with pair comparison. However, if no such superior option exists, the chosen option may depend on chance or on the chairperson. Condorcet discovered this over 200 years ago. Inset 12.3 describes Condorcet's so-called voting paradox.

Inset 12.3 Condorcet's voting paradox (Text based on Bamberg and Coenenberg 2002, pp. 253 ff.)

The following figure shows the preference profiles of three people in reference to three options. As can be seen from the figure:

- X and Z prefer option a to option b
- X and Y prefer option b to option c and
- Y and Z prefer option c to option a

Individuals / Individual preference orders	**X**	**Y**	**Z**
Preference 1	a	b	c
Preference 2	b	c	a
Preference 3	c	a	b

X, Y and Z = member of the first decision group
a, b and c = options

The preference profiles underlying Condorcet's voting paradox

If the first vote takes place between a and b, a wins. This option will then be matched against c, and c will be chosen. However, if first b and c are compared, b is preferred. Then, b is compared to a, and a is chosen. If the chairperson, however, would like to see option b win, he must first require a pair comparison between a and c. In this pair comparison, c will win. In the second vote, c is then compared to b, and b is preferred.

The conclusion from Condorcet's voting paradox is simple: if no superior option exists, the option that is chosen will be a matter of chance or of the power of the chairperson. It is possible to draw lots to determine the options for the initial pair comparison; in this case, the winning option is a chance result. If the chairperson can determine the sequence, his preferred option will win provided he knows the preferences of the group members and sets up the vote sequence accordingly.

12.3.5 Blin and Whinston's Approach for Forming a Collective Preference Order

Blin and Whinston (1974, pp. 28 ff.) propose to use the individual orders of preference to determine intensities of preference of the options within the group. These intensities then form the basis for determining the collective order of preference. This approach, which is based on fuzzy logic, is presented below using an example from Rommelfanger and Eickemeier (2002, pp. 207 ff.).

A group of ten people must rank the four truck models a to d. Figure 12.3 shows the preference profile of the group. As can be seen from the figure, all ten group members prefer a to b, for example, while only six prefer a to c. By analyzing the rankings in this way, a matrix with the preference intensities of the group can be produced, as shown in Fig. 12.4.

In the next step, all the collective orders of preference are now determined that are compatible with the highest intensity of preference. The highest intensity of preference favors a over b by 10:0. Twelve orders of preference are compatible with this:

(a > b > c > d); (a > b > d > c); (a > c > b > d);
(a > c > d > b); (a > d > b > c); (a > d > c > b);
(c > a > b > d); (c > a > d > b); (c > d > a > b);
(d > a > b > c); (d > a > c > b); (d > c > a > b)

Next, all the orders that are also compatible with the second-highest preference intensity are selected from these 12 collective orders of preference. This is the preference for d over c by 9:1. Based on this, 6 of the 12 orders of preference

Individuals / Preference	Q	R	S	T	U	V	W	X	Y	Z
Preference 1	a	d	d	d	a	c	d	d	a	d
Preference 2	b	c	c	c	b	a	a	a	d	a
Preference 3	d	a	a	a	d	b	c	c	c	b
Preference 4	c	b	b	b	c	d	b	b	b	c

Q, R ... Z = members of the decision group
a, b, c and d = options

Fig. 12.3 Preference profile of the group (adapted from Rommelfanger and Eickemeier 2002, p. 210)

Options \ Preferred to	**a**	**b**	**c**	**d**
a	-	10	6	4
b	0	-	3	3
c	4	7	-	1
d	6	7	9	-

a, b, c and d = options

Fig. 12.4 Preference intensities of the group

must be ruled out. The following six collective orders of preference remain in the race:

(a > b > d > c); (a > d > b > c); (a > d > c > b);
(d > a > b > c); (d > a > c > b); (d > c > a > b)

The third-highest preference intensity is 7:3 for c over b and also for d over b. Taking both of these into account simultaneously, only three orders of preference remain in the race:

(a > d > c > b); (d > a > c > b); (d > c > a > b)

The fourth-highest preference intensity also exists twice: a is preferred to c, as is d to a, with an intensity of 6:4. Only the order of preference d > a > c > b simultaneously considers these two preference intensities. It thus becomes the order of preference of the group.

In Fig. 12.5, the sum of the preference intensities underlying all 24 possible orders of preference is determined. The chosen order of preference has the highest sum of preference intensities. This shows that Blin and Whinston's procedure is reasonable.

12.3.6 Saaty's Analytic Hierarchical Process for Forming a Collective Preference Order

Saaty's Analytical Hierarchical Process (= AHP) is a problem-solving method for complex decision problems (see e.g., Saaty 1980). It allows modeling the decision situation, evaluating the options, and forming a preference order. The method can be used for individual decisions. However, it is particularly suitable for collective decisions and is mainly used in this case (see Dellmann and Grünig 1999, p. 34).

Orders of preference	Preference intensities underlying the orders of preference	Sums of the preference intensities
a>b>c>d	10 + 6 + 4 + 3 + 3 + 1	27
a>b>d>c	10 + 4 + 6 + 3 + 3 + 9	35
a>c>b>d	6 + 10 + 4 + 7 + 1 + 3	31
a>c>d>b	6 + 4 + 10 + 1 + 7 + 7	35
a>d>b>c	4 + 10 + 6 + 7 + 9 + 3	39
a>d>c>b	4 + 6 + 10 + 9 + 7 + 7	43
b>a>c>d	0 + 3 + 3 + 6 + 4 + 1	17
b>a>d>c	0 + 3 + 3 + 4 + 6 + 9	25
b>c>a>d	3 + 0 + 3 + 4 + 1 + 4	15
b>c>d>a	3 + 3 + 0 + 1 + 4 + 6	17
b>d>a>c	3 + 0 + 3 + 6 + 9 + 6	27
b>d>c>a	3 + 3 + 0 + 9 + 6 + 4	25
c>a>b>d	4 + 7 + 1 + 10 + 4 + 3	29
c>a>d>b	4 + 1 + 7 + 4 + 10 + 7	33
c>b>a>d	7 + 4 + 1 + 0 + 3 + 4	19
c>b>d>a	7 + 1 + 4 + 3 + 0 + 6	21
c>d>a>b	1 + 4 + 7 + 6 + 7 + 10	35
c>d>b>a	1 + 7 + 4 + 7 + 6 + 0	25
d>a>b>c	6 + 7 + 9 + 10 + 6 + 3	41
d>a>c>b	**6 + 9 + 7 + 6 + 10 + 7**	**45**
d>b>a>c	7 + 6 + 9 + 0 + 3 + 6	31
d>b>c>a	7 + 9 + 6 + 3 + 0 + 4	29
d>c>a>b	9 + 6 + 7 + 4 + 7 + 10	43
d>c>b>a	9 + 7 + 6 + 7 + 4 + 0	33

Fig. 12.5 Sums of the preference intensities of the 24 possible collective preference orders

First, the three components of the term “AHP” are briefly explained:

- “Analytical” means that the overriding goal is broken down into criteria. The options can be compared with respect to both qualitative and quantitative crite-

ria. The weighting of the criteria and the overall evaluation of the options are determined with mathematics.
- "Hierarchical" refers to the representation of criteria, environmental conditions, and options. These are always arranged on different hierarchical levels.
- "Process" indicates that the solution of the complex decision problem is developed based on a sequence of steps.

The AHP approach consists of five steps, which are briefly described below (see Dellmann and Grünig 1999, pp. 33 ff.).

1. In Step 1, the elements of the model are determined. This means defining the variables relevant to the decision. In addition to the overriding goal, decision criteria, environmental conditions, and options must be included. To enable a decision, at least two options must be available.
2. In Step 2, the problem structure is designed as a hierarchy. The overriding goal is always at the top of the hierarchy, and the options are always at the bottom of the hierarchy. The criteria, the subcriteria, and, if necessary, the environmental conditions are arranged at intermediate levels. Except for the top of the hierarchy, each level must have at least two elements. The elements on the lower levels are hierarchically linked to the elements of the upper levels. Figure 12.6 shows such a hierarchy.
3. In Step 3, the priorities are determined. A priority is the relative importance or the relative influence of an element on a superordinate element. As far as possible, the priorities are measured on ratio scales. With quantitative data, which can only be measured on interval scales (e.g., temperature), and with qualitative data

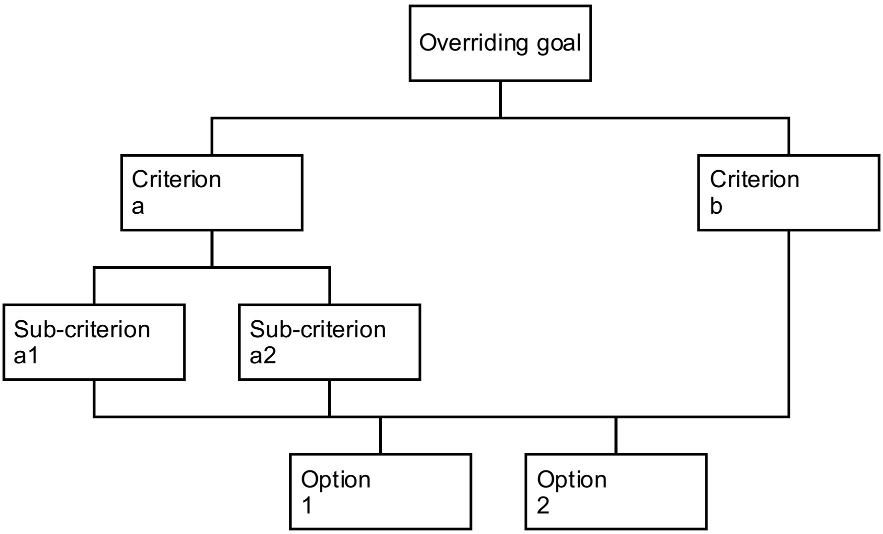

Fig. 12.6 Example of a four-level hierarchy

Value	Definition	Explanation/Comment/Description
1	Equal importance	Two elements are of equal importance for fulfilling a hierarchically superior criterion.
3	Slightly greater importance	One element is marginally preferred to the other.
5	Significantly greater importance	One element is clearly preferred to the other.
7	Much greater importance	One element is very strongly preferred to the other.
9	Maximally greater importance	The supremacy of one element is absolute.

Fig. 12.7 The Saaty scale

(e.g., attractiveness), the priorities are determined with the help of pair comparisons. By comparing pairs of elements in relation to a superordinate element, relative preferences are produced. These are then recorded in a matrix. The Saaty scale, represented in Fig. 12.7, forms the basis for this evaluation. The scale encompasses the values 1–9 and their reciprocals. If the priorities are determined by pair comparisons, their consistency must be tested. If it is insufficient, the evaluation must be repeated. Once a consistent pair-comparison matrix is available, the eigenvectors of this matrix are determined. This is done by transforming the absolute numerical values into normalized values for which the sum of all the values is 1. This allows data from different scales to be linked.

4. The overall priorities determined in Step 4 represent the result. The overall priorities express the relative preference of the options. The overall priorities are determined by continually multiplying and adding the priorities from the highest to the lowest level of the hierarchy.
5. The stability of the solution is checked with sensitivity analysis in Step 5. This examines how strongly the result reacts when the relative importances or influences of elements are varied.

Saaty's approach is particularly well-suited to group decision-making for three reasons:

- The common modeling in Steps 1 and 2 generates a shared view of the problem. In Step 1, all group members can bring in important elements of the problem from their point of view. In Step 2, the group designs the problem structure

together. However, the rule that the overriding goal be placed at the top and the options at the bottom must always be followed.
- Determining the weightings of the criteria, assessing the environmental conditions, and evaluating the options in Step 3 take place systematically and transparently. The systematic procedure of the method prevents the group from losing the overview. Transparency requires that the group members must put forward their judgments openly and cannot hide behind the collective. Different assessments can be discussed.
- Finally, the AHP method reveals inconsistent individual and group judgments and requires their revision. This can produce a considerable quality gain in the decision. However, it requires some tact on the part of the group leader, who must point out to individual members the contradictions in their judgments and ask them for revisions.

In Sect. 12.2.2 on the decision behavior of groups, measures to make it more difficult or impossible for group members to hide behind the group were recommended. The use of Saaty's AHP approach represents one such measure.

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Final Remarks 13

The book focuses on the heuristic problem-solving procedure introduced in Chap. 6 and described in Chaps. 7–9. Figure 13.1 recaps the procedure with its steps and substeps. It can be applied to solve complex decision problems such as company takeovers, reorganizations, grave quality problems, or serious conflicts. The procedure can also help solve decision problems with unclear goals and insufficient information. No matter how difficult the problem may be, the proposed general heuristic problem-solving procedure usually leads to at least a satisfactory solution. This outcome is achieved by breaking down the complex task into subtasks and placing them in a reasonable order. This sequence of tasks and subtasks guarantees an effective and systematic process and allows the actor to concentrate on the content challenges.

The authors hope that the proposed problem-solving method will prove helpful in many complex decision problems. However, working on complex problems and developing satisfactory to good solutions is more than an intellectual challenge. Often, much depends on the decision. Accordingly, executives are under psychological pressure. In such a situation, success is only possible for those who remain calm. Unfortunately, this book is unable to contribute anything to solving this issue.

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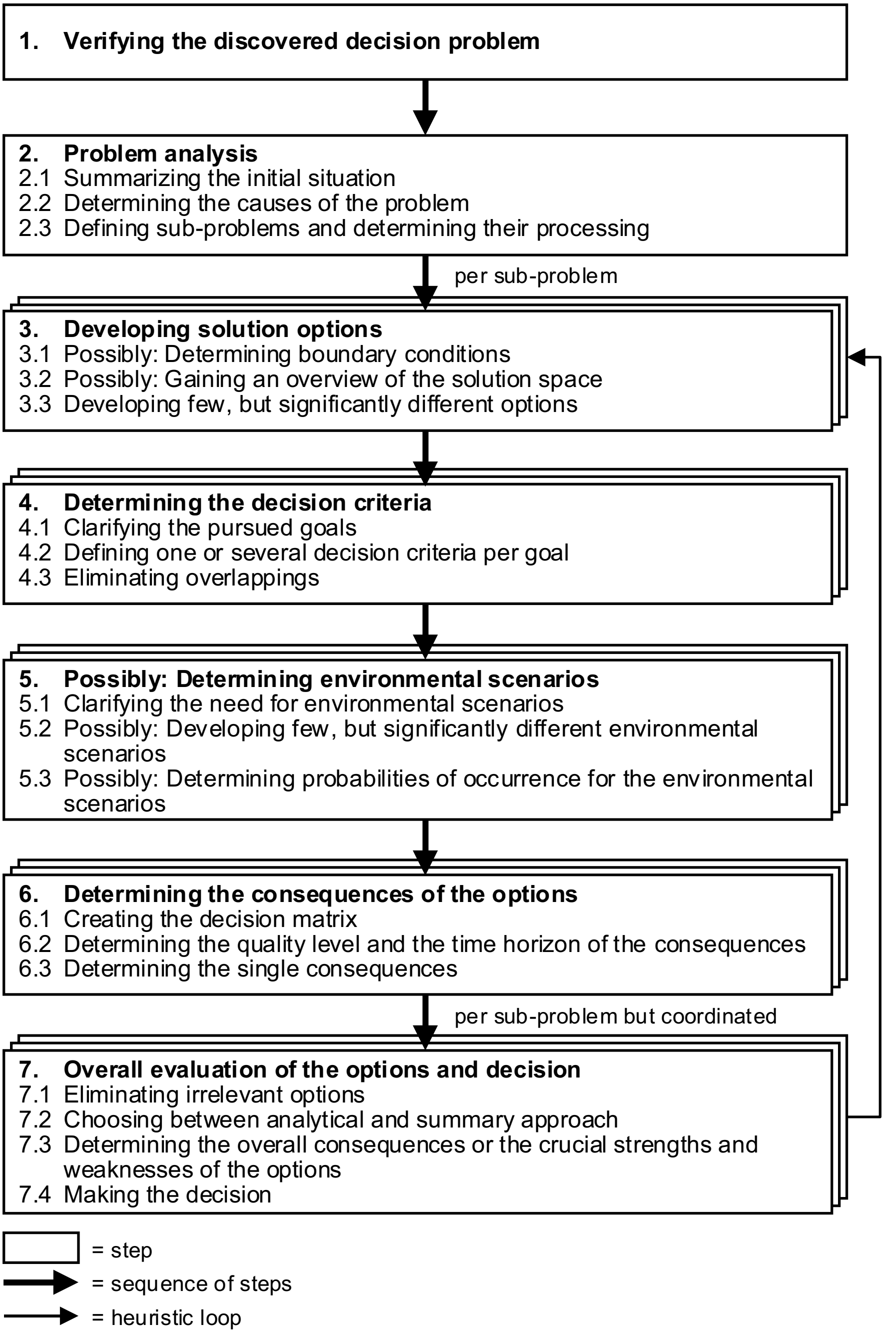

Fig. 13.1 The general heuristic problem-solving procedure

Glossary

Actor Person or group of people who takes a decision. The second case is known as a collective decision

Alternative Option

Alternative space Solution space

Certain decision problem Decision problem in which the environmental developments can be predicted with reasonable certainty. Therefore, no environmental scenarios are developed

Collective decision Decision made jointly by several people. Decision-making is more complicated in a collective decision because the people involved have different, sometimes strongly divergent, goal systems. In addition, different people judge differently the degree of goal achievement of the options under discussion. Therefore, rules are needed to aggregate the individual orders of preference into a collective order of preference. Arrow formulated requirements for such an aggregation mechanism and proved that they can only be fulfilled simultaneously in exceptional cases

Consequence The relevant effects of an option are called consequences. The decision criteria specify the relevant types of consequences. The consequences of an option are usually represented by several single consequences, which can be summarized into the overall consequence by applying decision maxims

Consequence type The consequence type is a category of consequences. The decision criteria determine the consequence types that are relevant in a specific decision problem

Decision The final step of the problem-solving process in which the best option is selected

Decision criterion Since goals are often vaguely formulated, they must be specified before they can be used in a specific decision problem to assess the options. A concrete formulation of a goal regarding the assessment of options in a specific decision problem is called decision criterion. In most cases, several decision criteria must be defined to enable the measurement of the effects of the options concerning one goal

Decision matrix Matrix containing all relevant information about a decision to be made. Mostly the options are listed on the vertical dimension. The hori-

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zontal dimension shows the decision criteria or types of consequences and, if existing, the environmental scenarios. In the fields of the matrix are the single consequences

Decision maxim Decision maxims are systems of rules for summarizing the single consequences of the options to their overall consequences. Decision maxims thus presuppose the options and their consequences. There are decision maxims for overcoming risk, for overcoming uncertainty, and for overcoming polyvalence

Decision problem A problem is a difference between a current and a target situation. A decision problem is present if the actor has at least two options to eliminate or reduce the difference

Decision process Problem-solving procedure

Decision sequence A decision sequence exists when a decision made today opens possibilities or needs for further decisions in the future. The available options for future decisions and/or their consequences depend on the option selected today. Decision sequences are usually represented with the help of decision trees

Decision theory A summary of the findings of management research on decision-making. Decision theory can be subdivided into decision logic, descriptive or explicative decision theory and prescriptive decision theory

Decision tree Decision trees are graphical representations of decision sequences. Decision trees always start with a decision node and then specify further decision nodes and situation or chance nodes. At the end of the individual branches are the single consequences

Decision variable A variable that the actor controls. Normally, an actor has in a decision problem several decision variables, each with a given spectrum of values. The decision variables and their values determine the solution space and form the basis for developing solution options

Environmental scenario In a specific decision problem, several possible environmental scenarios arise if the future values of important environment variables cannot be predicted with reasonable certainty. They usually influence at least a part of the single consequences of the options. Depending on whether probabilities of occurrence can be assigned to the environmental scenarios, a risk decision or an uncertain decision problem results

Environmental variable A variable that the actor cannot influence but exerts itself an influence on single consequences of the options in a decision problem. Often, the actor cannot predict the future value of individual environmental variables but must consider several possible values for them. They form in this case the basis of the environmental scenarios

Goal A goal is a target state which is therefore maintained or strived for. Goals are often not specified precisely but described only vaguely. Normally the actor has several goals and thus has a goal system. The goals form the basis for the discovery of decision problems and for making decisions

Goal system Usually, an actor pursues several goals simultaneously and thus has a goal system. This forms the basis for the discovery of decision problems and for making decisions. The goal system is seldom entirely precise but often vaguely formulated. It may even contain contradictions

Heuristic principles Thinking rule that makes it possible for problem-solvers to render complex problems solvable. Heuristic principles form an important basis for heuristic problem-solving procedures. One important heuristic principle is, for example, problem factorization. It recommends decomposing a complex decision problem into sub-problems that can be solved in parallel and/or in sequence

Multivalent decision problem Decision problem in which the actor uses multiple decision criteria that are not arithmetically linked to assess the options

Option An option is a possibility with which the actor can reduce or eliminate the deviation of the actual situation from the desired situation. An option represents a combination of one value of each of the decision variables

Overall consequence Normally, the effects of an option are recorded in several single consequences. These can be summarized with the help of decision maxims into the overall consequence of the option

Problem Decision problem

Problem indicator Variable whose change can indicate a decision problem. Problem indicators are the central elements of a problem-finding system

Problem solving process Problem-solving procedure

Problem-finding system part of the information system that serves, among other things or exclusively, to discover decision problems

Problem-solving procedure system of intersubjectively comprehensible rules of information obtaining and processing. The problem-solving procedures can be categorized as general and specific ones according to the scope of problems to which they can be applied. They can also be categorized, according to the solution quality obtained, into analytic procedures or algorithms and heuristic procedures. The former yields an optimal solution but has restrictive formal application conditions. The latter leads as a rule only to a satisfactory solution. The advantage of such procedures is that they have few or no formal application restrictions

Rational decision There are two diverging understandings of when a decision is rational. Substantive rationality demands that the goals pursued must be correct or rational and that the decision process must be rational. Formal rationality only requires that the decision process be rational. Since goals are generally regarded as subjective, there are no right and wrong goals and, thus, there is no substantial rationality. Management science is therefore oriented towards formal rationality

Risk decision problem Decision problem in which the development of the environment cannot be predicted with reasonable certainty. Therefore, several possible environmental scenarios are developed. In contrast to an uncertain decision problem, probabilities can be attributed to them

Scenario Environmental scenario

Sequential decision Decision sequence

Single consequence One effect of an option. The single consequences of a decision problem are defined by the decision matrix or the decision tree

Solution option Option

Solution space The solution space of a decision problem is defined by the decision variables and their values. The options developed to solve the problem should cover this solution space as well as possible

Uncertain decision problem Decision problem in which the development of the environment cannot be predicted with reasonable certainty. Therefore, several possible environmental scenarios are developed. In contrast to a risk decision problem, no probabilities of occurrence can be attributed to them

Univalent decision problem Decision problem in which the actor uses only one decision criterion to assess the options. We can also speak of a univalent decision if the actor uses several criteria that are related arithmetically

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