

CONTRIBUTIONS  
TO MANAGEMENT SCIENCE

Eric Kasper

# Internal Research & Development Markets



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# Internal Research & Development Markets



# Contributions to Management Science

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## **Dedication**

With love and gratitude dedicated to  
my mother Angela & my father Franz,  
both of my brothers Claus & Simon,  
and my beloved wife Bilge.

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Eric Kasper

Römerberg, April 2006

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# 1 Introduction

## 1.1 Research problem

### 1.1.1 Central problem: Allocation of scarce resources in Research & Development

In times of global markets, increasing competition and shorter product life cycles the effective and efficient management of industrial Research & Development (R&D) activities is of central importance for companies as well as for the whole economy (Miller & Morris, 1999). Thus, the increase of the innovation strength is for many companies one of the most important challenges, in order to secure a sustainable profit and turnover growth for the coming years.

The European Foundation for Quality Management (1999 p.7) describes innovation as *“the structural process that organisations have in place (supported by different structural and organisational enablers) to continuously generate a stream of Opportunity Ideas (product/service and/or process-innovations). These ideas are then tracked and assessed in order to generate and launch New Products, New Services or New Product features into the marketplace.”* In the struggle for market shares and competitive ability the long-term success of an enterprise thus increasingly depends on its achievements in R&D (Boer, 1999).

In general, corporations group their innovation activities in the R&D function. The R&D function can be separated into the research function (basic research, applied research, methodology research), and the development function (development of new products and processes or enhancement of existing products and processes). The core of innovation activities are projects, which aim at the development of new or at the enhancement of existing technologies, products and processes.

R&D projects arise in many different ways (Twiss, 1994; Budworth, 1996; Boer, 1999; Miller & Morris, 1999):

- as a result of the ‘market pull’ exerted by customers’ desires, competitors’ activities and marketing staff’s ideas for new products;
- as a result of the ‘technology push’ exerted by the results of internal research and the external achievements of scientists and competitors;
- for reasons of safety, cost and location;
- as a result of the strategic objectives of an enterprise regarding the opening up of new areas of business or globalisation; and
- as a result of external factors, such as society demand or new legislation, which lead to changes in products or processes.

The results of R&D projects consist of scientific findings, knowledge and product as well as process know-how which is translated into material results (e.g. products) at the application stage.

Within R&D the following economic problem emerges: How could and should scarce resources (human resources, funds etc.) be allocated between competing projects?

In this context Twiss (1994 p.123) states that “*project selection is one of the two most critical and difficult decision areas in R&D management. Of equal importance is project termination due to the high proportion of projects discontinued before their development is completed.*” In other words, the initial allocation decisions at the beginning of projects as well as the reallocation decisions during the implementation of projects are crucial for a successful R&D management.

The difficulties in project selection and portfolio management can be explained by certain characteristics of R&D projects, such as a high degree of uncertainty, complexity and unstructuredness (Nippa & Reichwald, 1990). Moreover, each R&D project can be understood as an investment (Budworth, 1996); however, the investment in a certain R&D project sometimes differs substantially from an investment in tangible assets.

On the one hand the time period from starting a project up to the achievement of first incomes can be very long. For example, the development of new pharmaceuticals can last more than 10 years until first revenues can be achieved. On the other hand there are immense market risks and especially technical risks involved when conducting R&D projects. For instance, in the pharmaceutical sector only 3-5 out of 100 projects will be finished – without saying that these projects will be a market success. According to a study of Cooper & Kleinschmidt (1990) only 25% of all new launched products – on the average of different industries – are successfully. A further evaluation problem arises from the following aspect: R&D projects, especially Research & Technology (R&T) projects, which do not only aim at a certain market or customer group, often create synergies to other R&D projects or help to achieve better technological or market positions that must be included in the project evaluation as well (Twiss, 1994; Boer, 1999; Völker, 2000).

The remarks above clarify that the effective and efficient project selection and the associated allocation of scarce R&D resources are fraught with enormous difficulties in practice. Only if structures and processes in R&D are in line with the strategy of the enterprise and market needs, costs can be avoided, products can be launched earlier and thus higher profits can be obtained.

Although many companies have improved their R&D processes and structures in recent years, there is still a set of challenges existing: Baratte & Kirsten (2003), for example, mention the transparent selection and structuring of the R&D project portfolio or the transition from rigid and hierarchical organisational structures to more flexible ones. In this context Miller & Morris (1999) describe hierarchical organisation structures as “*obstacle to innovation*” (Miller & Morris, 1999, p.205).

The mentioned examples illustrate that especially allocation problems are still of high importance. Thus, the main challenge is to allocate the existing scarce resources (personnel, material, capital etc.) to those R&D projects, which promise the highest value contribution for the enterprise (Foster, 1986).

Fundamentally, two kinds of resource allocation mechanisms can be differentiated:

- the centralised administrative allocation by an instruction-authorized instance (hierarchy), and
- the market-driven allocation via a completely decentralised coordination between equal partners (market).

Between hierarchy and market a multitude of hybrid forms of resource allocation exist. The discussion which of these forms of resource allocation is more efficient is not new and goes back on Williamson (1975). In recent years there has been a trend towards more market-like solutions, which resulted in the creation of profit center organisations and led to substantial improvements in productivity and efficiency (Halal, Geranmayeh & Pourdehnad, 1993). However, the R&D field is still dominated by rather hierarchical, administrative structures and processes, as it is illustrated in the conducted case studies (see chapter 4 and appendix 1).

The main weaknesses of hierarchical, administrative structures are particularly the resulting long decision procedures as well as the lack of information of the involved decision-makers, which may lead to inefficiencies (see section 2.2.1). Moreover, asymmetric information can lead to an opportunistic behaviour of subordinates (Leibenstein, 1987; Fisher, Frederickson & Peffer, 2002).

The establishment of internal markets (see sections 2.3, 2.4 and 3.2) could possibly contribute to the solution of the problems mentioned above because they combine control of performance with freedom of operations, and thus, provide two major advantages (Halal, Geranmayeh & Pourdehnad, 1993):

- they ensure accountability for performance, and
- they encourage creative entrepreneurial action.

The following section sorts the research topic ‘internal R&D markets’ into the broader context and illustrates that the present investigation has to be viewed from an ‘Industrial Organisation’ perspective.

### 1.1.2 Reorganisation concepts – trend towards internal markets

There are several reasons for searching for promising organisational concepts (Raab-Stahl, 1999). Often it is the potential success, which is prognosticated by the 'inventors' of new organisational concepts or by consultants, that prompts companies to reorganisations.

Further motives for reorganisations are examples in the literature that show a relationship between improvements in the achievement of companies' targets and the efficiency of the implemented organisational solution (Zeitz, Mittal & McAnlay, 1999; Meyer & Heimerl-Wagner, 2000).

The reorganisation efforts in the companies aim particularly at increasing the efficiency regarding the strategic objectives 'costs,' 'time' and 'customer use'. In this respect it is important to overcome the deficits of traditional organisational structures by suitable structural adjustments, respectively, by the implementation of new mechanisms. This should be achieved particularly through the preservation and/or creation of an extensive flexibility regarding the internal decision-making processes (Volberda, 1992; von der Oelsnitz, 1994; Volberda, 1998).

In this context flexibility can be described as follows: On the one hand it is about the ability to keep open a multitude of alternative action options in order to react to unexpected changes in the decision environment (decision flexibility). Concerning the discussion about adaptable organisational concepts, flexibility means that flexible structures should enable a fast and at the same time a high-quality adjustment of individual organisational units (in the research context: R&D units) to changed conditions, without resulting in adjustment- or coordination-requirements for the remaining elements of the enterprise (adjustment flexibility).

A further goal of reorganisation efforts is to develop further the knowledge and abilities of all co-workers in order to achieve corporate goals. In the knowledge-intensive R&D field this is especially important, in order to use the innovation potential of the enterprise as optimally as possible. In this context it is of special importance to ensure a permanent support of individual and organisational learning so that the co-workers are *able* and *ready* to fulfil their tasks, respectively, to make decisions in accordance with the company's targets.

The demanded *ability* means that decisions should be made as far as possible in those units, in which the necessary knowledge is available (decentralisation). The following statement of Hayek (1945 p.524) underpins the concept of decentralisation:

“If we can agree that the economic problem of society is mainly one of rapid adaptation to changes in the particular circumstances of time and place, it would seem to follow that the ultimate decision must be left to the people who are familiar with these circumstances, who know directly of the relevant changes and the resources available to meet them. We cannot expect that this problem will be solved by first communicating all this knowledge to a central board which, after integrating all knowledge, issues its orders. We must solve it by some form of decentralisation.”

The criterion *readiness*, on the other hand, aims at the consistent promotion of the intrinsic and extrinsic co-worker motivation. Possible incentives for R&D co-workers are for example: Possibilities to participate in seminars, training possibilities, social security contributions, salaries, job security, promotion prospects within the R&D field, bonus for successfully finished projects, flexible working hours, temporary exemption from work to pursue own R&D activities and publications (Domsch, 1984; Milgrom & Roberts, 1992).

Further important impulses for the development of innovative organisational structures are based on the ‘resource-based view of corporate strategy’ (Wernerfelt, 1994; Barney, 1991; Penrose, 1995). In contrast to the ‘market-based view of corporate strategy’ (Porter, 1980; Porter, 1985; Porter, 1994), which is concerned with the suitable positioning of the enterprise in the market in order to be competitive, the ‘resource-based view’ attributes the sustainable acquisition of competitive advantages to the specific abilities of the enterprise. These so-called core competencies must deliver their own value contribution and they should be difficult to imitate by the competitors in the long run (Prahalad & Hamel, 1990; Hamel & Prahalad, 1994).

Since organisation-specific knowledge embodies these characteristics to a strong extent, the implementation of efficient organisational concepts can be seen as a central leverage for the improvement of the competitive position. It can be argued that, due to the transition from the industrial society to the knowledge society with its tremendous changes in the market as well as in the technological and social environment, traditional organisational structures are no longer efficient (Heckscher, 1994). Thus, it can be assumed that centralistic, hierarchical organisational structures will no longer be up to the future challenges that arise from an increasingly complex and dynamic environment.

The most consistent proponents of internal markets state that the implementation of market-like regulations is an indispensable condition for the successful management of companies in times of increasing global competition. Hinterhuber (1993), for example, states that the creation of internal markets is the western way to increase the competitive ability of the enterprise. He argues that if one brings the advantages of the free market economy into medium-sized and large enterprises, then the development of western individualism and entrepreneurship will lead to a quantum leap in productivity and flexibility of the enterprises.

The practical relevance of market-like elements, such as profit centers or transfer prices, for the steering of companies is evidenced by a huge number of publications. The profit center concept, for example, is discussed by Frese (1995) or the use of transfer prices is illustrated in Vancil (1978) and Tang (1993).

In this context it is remarkable that in recent years a trend was to be determined in many companies to apply more market-like solutions within resource allocation processes (Klingenberg & Graumann, 2000; Schweiker & Utikal, 2000). Often internal markets were created; e.g. to date companies often organise their functions – such as logistics, technical services, production, human resources, IT etc. – as so-called profit centers, what led to substantial improvements in productivity and efficiency (Halal, Geranmayeh & Pourdehnad, 1993).

But, is the establishment of internal markets also possible and beneficial in complex R&D contexts?

### **1.1.3 Are market-like forms of resource allocation suitable for R&D resource allocation?**

Despite the potential advantages of market-like solutions a rather hierarchical, administrative organisation still prevails in the R&D field. This is underpinned by the screened literature in the field of innovation management, which is mainly concerned with hierarchical resource allocation processes (Twiss, 1994; Budworth, 1996; Specht & Beckmann, 1996; Boer, 1999). The main obstacle regarding a more market-oriented organisation of the R&D resource allocation seems to be the already mentioned characteristics of the R&D projects or services. It appears that the long time-to-market and the high level of uncertainty prevent the application of market-driven forms of resource allocation.

However, the application of internal market mechanisms for the project selection and the corresponding allocation of resources should not be impossible (Spremann, 1998; Spremann, 2001). This was also confirmed by the case studies, which were conducted in a set of technology-intensive companies (see chapter 4 and appendix 1). It was shown that market-like elements are sporadically applied within the scope of R&D resource allocation processes.

The most often applied market element is the so-called direct assignment. In this case the requesting divisions and/or business units instruct the supplying R&D units to implement certain R&D projects or services for them. Twiss (1994 p.52) defines this element as follows: *“In some large multinational companies the individual business units pay for the research done on their behalf. The central research laboratory then assumes some of the characteristics of an external contract organisation.”*

Furthermore, a tendency could be identified, which showed that some companies aim at a more market-oriented organisation of their R&D activities. For example, the director of BASF-Research demands a more *“market-oriented innovation process”* (Peitz, 2002 p.2) and thereby stresses the increasing importance of markets and customers within the scope of R&D activities.

However, internal R&D markets are not an established standard yet and are almost unexplored in the existing literature (see chapter 2). This leads to the following generic research questions and objectives.

## 1.2 Generic research questions and objectives

Section 1.1 described the underlying research problem and reviewed some basic literature. In this context it was emphasised that the effective and efficient allocation of scarce R&D resources is a central challenge for companies that have to cope with rapid change and fierce global competition. Moreover, the following two main forms of resource allocation were differentiated: The administrative, hierarchical allocation on the one hand and the allocation via internal markets on the other hand. In between there are a multitude of hybrid forms of resource allocation that are characterised by a mix of hierarchical and market-like elements.

Previous studies have mainly been concerned with traditional hierarchical forms of R&D resource allocation and the associated problems and weaknesses. However, the potential of implementing internal R&D markets has been completely disregarded so far. This is remarkable since the establishment of internal markets can offer valuable advantages to companies. Whereas some authors emphasise the reduction of complexity, other authors attach great importance to the disciplinary effects of competition, the flexibility and the innovative power of market systems.

Thus, this research was designed as an exploratory study to investigate whether internal R&D markets can add value to the different R&D activities of companies. This innovative organisational concept is largely unexplored in R&D contexts and can potentially contribute to overcome the weaknesses of traditional hierarchical forms of resource allocation. On the basis of the research problem which was discussed in the previous section and the identified research ‘lacunae’ a set of research opportunities resulted. These research opportunities constitute the base for the present investigation and are reflected in the following generic research questions concerning the topic ‘internal R&D markets’:

- Which types of R&D projects can be differentiated in practice?
- Are there project type-specific differences concerning the R&D resource allocation?
- Can scarce R&D resources be allocated by the direct interaction of supply and demand (market-driven resource allocation)?
- How should the design of an internal R&D market look like?

The research undertaken in the present investigation provides answers to these research questions and thus makes significant contributions to the literature on innovation management, respectively, R&D management.

Based on the generic research questions mentioned above the following research objectives can be derived:

- First of all the thesis investigates if there are differences across R&D project types concerning certain criteria.
- Then the research work shows for which types of R&D projects market-driven forms of resource allocation are possible.
- Moreover, the inquiry illustrates for which types of R&D projects market-driven forms of resource allocation are more effective and/or efficient than hierarchical forms of resource allocation.
- Finally, the thesis aims at deriving policy recommendations concerning the design of an internal R&D market.

The underlying research methodology, which was applied for answering the research questions and for fulfilling the research objectives, is briefly introduced in the following section.

### 1.3 Research methodology

Given the generic research questions and research objectives stated above a mixed-method approach appeared to be suitable for the present investigation. This means that both qualitative and quantitative methods of data collection were used (Bryman, 1988; Dey, 1993; Easterby-Smith, Thorpe & Lowe, 2002).

Collis & Hussey (2003) argue that it is quite usual to apply a mixture of approaches when conducting business research. *“The use of different research approaches, methods and techniques in the same study is known as triangulation and can overcome the potential bias and sterility of a single-method approach”* (Collis & Hussey, 2003 p.78). The main advantage of triangulation is the greater validity and reliability of the research results (Denzin, 1978).

Easterby-Smith, Thorpe & Lowe (2002) distinguish between the following types of triangulation:

- data triangulation,
- investigator triangulation,
- methodological triangulation, and
- triangulation of theories.

Within the scope of the present investigation a methodological triangulation was applied.<sup>1</sup> Methodological triangulation can be classified as simultaneous or sequential (Morse, 1991, p. 120):

“Simultaneous triangulation is the use of the qualitative and quantitative methods at the same time. In this case, there is limited interaction between the two datasets during the data collection, but the findings complement one another at the end of the study. Sequential triangulation is used if the results of one method are essential for planning the next method. The qualitative method is completed before the quantitative method is implemented or vice versa.”

For the present inquiry a sequential triangulation of research methods was used, including case study research, survey research, and group interviews. This means that three different types of methods were used. Two of these were qualitative and one was quantitative. Thus, the intended research can be subdivided into three stages: (1) case study research, (2) survey research, and (3) group interviews.

In a first stage the qualitative **case study methodology** was applied (Yin, 1994). Therefore, the topic-relevant literature was analysed and based on the findings a catalogue of semi-structured questions for the subsequent expert interviews<sup>2</sup> was derived, which were conducted in nine technology-intensive companies (ABB, Abbott Laboratories, BASF, BMW, DaimlerChrysler, Henkel, Hilti, Roche and Syngenta).

On this basis case studies were provided, which document the current status of the R&D resource allocation as well as potential starting points for the application of internal market mechanisms in the R&D field (see chapter 4 and appendix 1).

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<sup>1</sup> Zikmund (2002), Collis & Hussey (2003) as well as Saunders, Lewis & Thornhill (2003) give an overview of the main quantitative and qualitative methods of data collection.

<sup>2</sup> In general, an interview can be defined as a purposeful discussion between two or more people (Kahn & Cannell, 1957).

This exploratory research stage was essential for the research in order to get a picture of the topic-related issues and to clarify the taxonomy (e.g. types of projects, market-driven resource allocation, effectiveness, efficiency etc.) before embarking on a questionnaire (Saunders, Lewis & Thornhill, 2003). This means that this first exploratory stage helped to clarify the research problem, identify the relevant variables as well as the relationships between these variables and thus built the basis for the derivation of specific hypotheses.

The remarks made above illustrate that the qualitative answers from the case study research played an important role within the research project since the analysis of these data provided the basis for the design of a concise questionnaire, which was needed for the subsequent survey stage.

In the second stage the quantitative **survey method** was applied (Dillman, 2000; Oppenheim, 2000). The findings from stage 1 as well as an extended literature review built the basis for the design of a questionnaire, which was needed for hypothesis-testing. It has to be noted at this juncture that first a German version of the questionnaire was developed which then was translated into an English version.

Within the scope of this empirical study a written postal survey was used as the basic research method. Questionnaires were sent to 281 huge R&D-intensive companies worldwide, which were mainly selected from the Fortune Global 500 Database. Thereby it was focused on the technology-intensive industries automotive, chemicals, electronics, pharmaceuticals and telecommunications.

Beside the test of the hypotheses the survey aimed at gathering data concerning:

- the characteristics of R&D project types,
- the R&D organisation,
- the R&D resource allocation, and
- the allocation result.

After data acquisition the raised data were statistically evaluated and the results were then analysed and interpreted. This means that the quantitative survey data provided the basis for hypothesis-testing and enabled the formulation of generalising statements concerning the topic 'internal R&D markets'.

The findings of the empirical studies described above mainly aimed at answering the following research questions (refer to section 2.5):

*RQ1: Are there differences across R&D project types concerning (1) the project characteristics, (2) the R&D organisation, (3) the R&D resource allocation, and (4) the allocation result?*

*RQ2: For which types of R&D projects are market-driven forms of resource allocation possible?*

*RQ3: For which types of R&D projects are market-driven forms of resource allocation more effective and/or efficient than hierarchical forms of resource allocation?*

Given these research questions, the quantitative analyses aimed at testing the following fundamental hypotheses that were derived from the conducted preliminary investigations:

- There are differences across R&D project types concerning the project characteristics.
- There are differences across R&D project types concerning the R&D organisation.
- There are differences across R&D project types concerning the application of market-driven forms of resource allocation.
- There are differences across R&D project types concerning the effectiveness and/or efficiency of market-driven forms of resource allocation.

These hypotheses were further refined on the basis of the case study results (see chapter 4). The corresponding hypothesis-tests as well as the analysis of the survey findings are presented in chapter 5.

Furthermore, the findings of the stages 1 and 2 provided the basis for final conclusions and for answering the fourth research question, which was:

*RQ4: How should an internal market within R&D be designed?*

In order to validate and verify the findings and to derive policy recommendations for the design of an internal R&D market a third stage was employed. Within this stage qualitative semi-structured **group interviews** with experts from the partner companies were conducted to clarify the content of some of the questionnaire results and to get at the meaning behind some of the data (Wass & Wells, 1994; Saunders, Lewis & Thornhill, 2003). The complete underlying research process, which is oriented on Zikmund (2002), is presented in Figure 1.

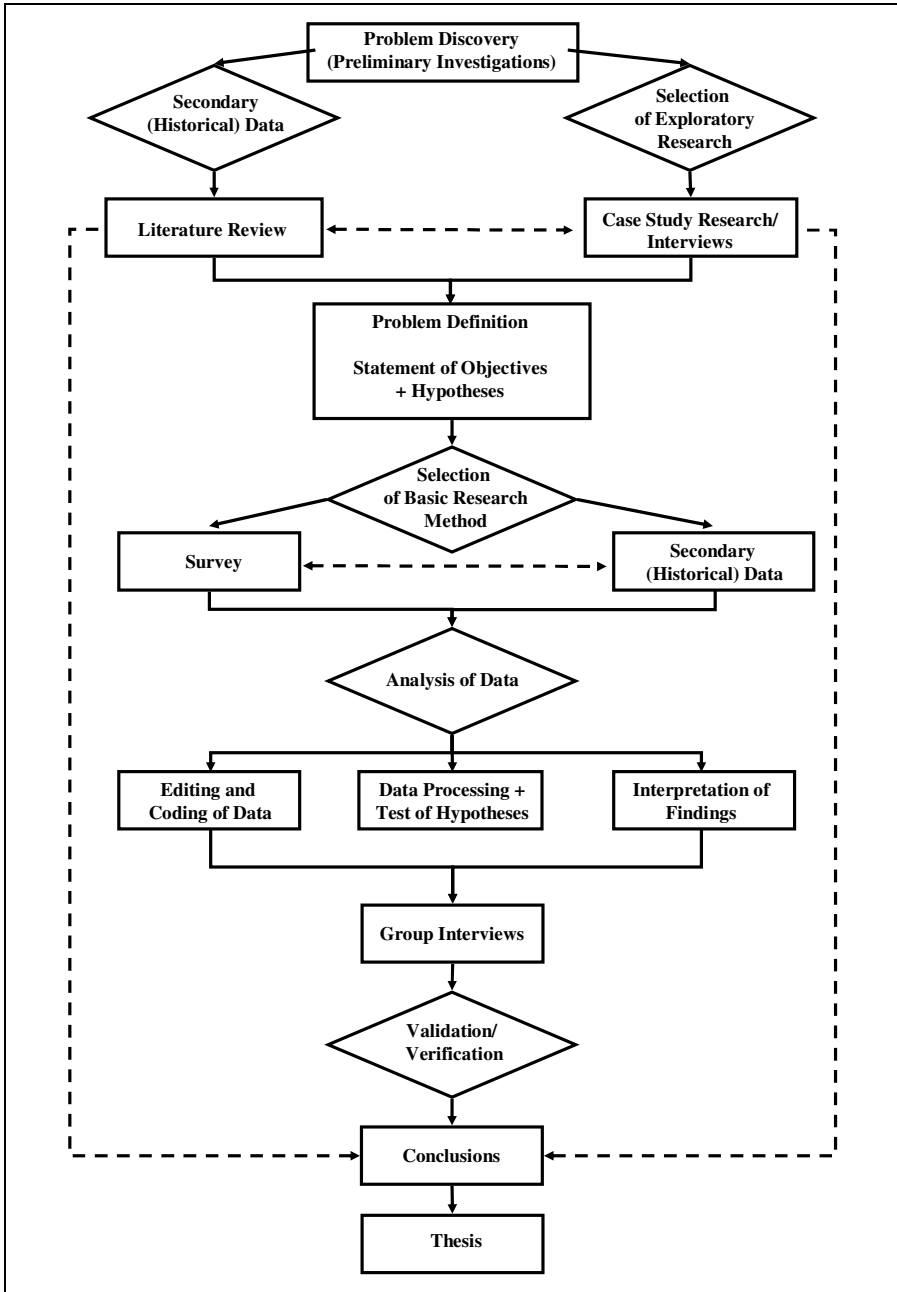


Figure 1: Research process

Zikmund (2002 p.59) describes the research process in its ideal-typical form as a succession of the following stages:

- problem definition,
- planning research design,
- planning of a sample,
- data acquisition,
- coding and analysis of the data,
- formulation of the results and conclusions, and
- definition of the new problems.

These individual phases are, however, not strictly separated from each other but overlap themselves and are interrelated. The research work that was conducted during the research project was oriented on this ideal-typical research process. The complete methodological approach is explained in more detail in chapter 3.

## **1.4 Outline of the thesis**

The thesis in hand is structured into seven chapters.

Chapter 1, the introduction, comprises the definition of the research problem (section 1.1), the statement of the generic research questions and objectives (section 1.2), a brief description of the methodological approach (section 1.3), and the outline of the thesis (section 1.4). Finally, section 1.5 provides some first conclusions and explains the novelty of the present investigation.

The following chapter 2 deals with the literature review concerning the state of the art of R&D resource allocation. Likewise, this chapter discusses new trends in this field and provides the theoretical underpinnings of the investigation.

Section 2.1 introduces into the research topic. Moreover, fundamental terms, such as R&D, innovation process, resource allocation etc., and relationships that are important for the basic understanding of the research topic, are explained.

The subsequent section 2.2 illustrates the state of the art of R&D resource allocation. Main emphasis has the traditional hierarchical resource allocation. In addition to that this section discusses recent developments in this field.

On this basis the topic 'internal markets' is identified as a major new trend. In consequence, section 2.3 presents an overview of the topic-relevant literature.

Thereafter, the theoretical underpinnings of the study are presented in section 2.4. Firstly, relevant basic theories are introduced before they are scrutinised with regard to the central research questions, namely: For which types of R&D projects are market-driven forms of resource allocation (a) possible and (b) more effective and/or efficient than hierarchical forms of resource allocation?

After a brief description of the traditional organisation theories (section 2.4.1) it is mainly focused on the neoclassical approaches (section 2.4.2) and the neoinstitutionalistic approaches, i.e. the property rights theory (section 2.4.3), the transaction cost theory (section 2.4.4) and the principal agent theory (section 2.4.5). Afterwards the concept of value management is introduced (section 2.4.6), which provides the theoretical base for the evaluation of alternative forms of resource allocation.

Eventually, the literature-related conclusions are drawn in section 2.5.

Before the empirical findings are analysed and discussed a detailed description of the methodological approach is presented in chapter 3.

In a first step, section 3.1 introduces the methodological components and their sequence.

Subsequently, based on the research problem and the research questions, a conceptual framework for the inquiry is developed in section 3.2. On the basis of the reference model 'external markets' a definition of an internal R&D market is developed, which secures a uniform understanding of the term. This framework thus builds the fundament for an efficient implementation of the empirical studies and constitutes a central prerequisite for valid and reliable research results.

Section 3.3 then discusses the data requirements associated with the inquiry. Moreover, the related conceptual and operational problems from the methodological and methods perspective are discussed.

The solution to these problems is a mixed-method approach, which is discussed in-depth in section 3.4. It is illustrated that a sequential triangulation of research methods was applied, including case study research, survey research, and group interviews.

Thereafter, in section 3.5, the applied methodology of exploratory case studies is paid some attention. Beside the definition and application of case studies this section is particularly concerned with the design and implementation of the case study research.

Furthermore, section 3.6 deals with the methodological approach regarding the conducted survey. Firstly, the underlying research model is introduced, which reflects the central hypotheses of the study. Then the research arrangements and instruments as well as the objects of investigation are discussed.

The following section 3.7 emphasises the necessity to validate and verify the findings of the survey by means of group interviews, in order to derive policy recommendations.

The ethical aspects and delimitations of the present investigation are discussed in section 3.8.

Eventually, the methodological limitations associated with the inquiry are outlined in section 3.9.

The following chapter 4 presents the empirical findings of the conducted case studies, which were implemented in a set of technology-intensive companies. On the basis of a cross-case analysis the central hypotheses are refined and specified.

After a short introduction (section 4.1), a typology of R&D projects is developed in section 4.2. Moreover, the characteristics of the different project types are explained. Furthermore, the analysis focuses on the R&D organisation (section 4.3), the R&D resource allocation (section 4.4) and the allocation result (section 4.5).

The findings of the case study research are summarised in section 4.6. Moreover, this section presents an overview of the testable hypotheses.

Subsequently, the derived hypotheses are tested within the scope of an international survey. The findings of this survey are presented in chapter 5.

The analysis components and their sequence are introduced in section 5.1. The presentation of the survey findings is oriented on the structure of the case study findings. Main emphasis has the investigation of project type-specific differences concerning the characteristics of R&D project types (section 5.2), the R&D organisation (section 5.3), the R&D resource allocation (section 5.4), and the allocation result (section 5.5). On this basis it is concluded for which R&D project types market-driven forms of resource allocation are most appropriate.

Finally, section 5.6 provides a summary and discussion of the major survey results.

In order to validate and verify the empirical findings a set of group interviews was conducted. The findings of these interviews are presented in chapter 6.

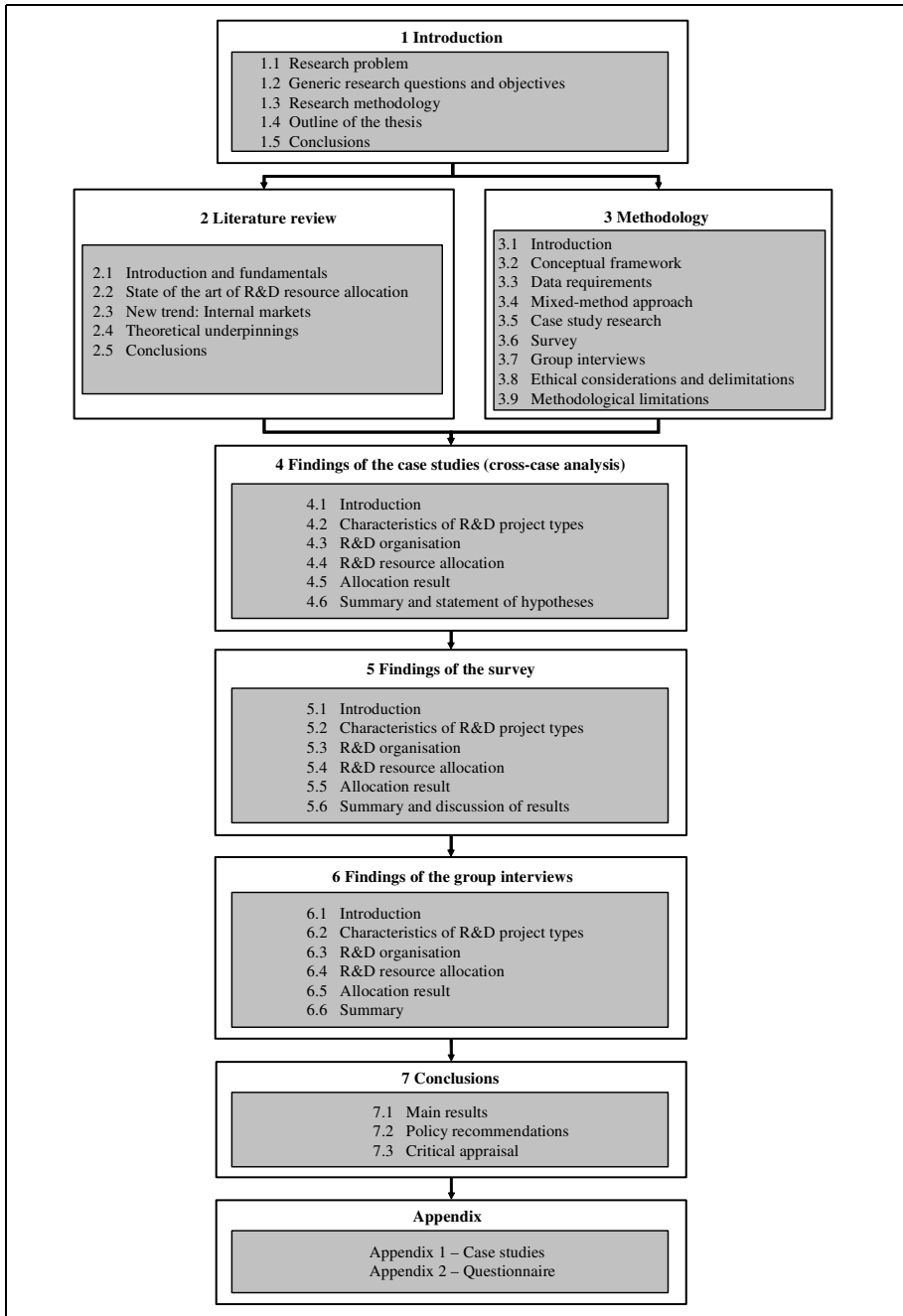
Section 6.1 introduces the analysis components and their sequence. The presentation of the group interview findings is oriented on the structure of the case study findings and the survey findings. Main emphasis has the confirmation of the empirical findings concerning the characteristics of R&D project types (section 6.2), the R&D organisation (section 6.3), the R&D resource allocation (section 6.4), and the allocation result (section 6.5).

Eventually, section 6.6 provides a summary and discussion of the major group interview results.

The final conclusions of the conducted research are shown in chapter 7. In a first step, the major research results of the thesis are summarised in section 7.1. The derived policy recommendations are subsequently presented in section 7.2. Finally, section 7.3 provides a critical appraisal of the work done. Moreover, this section gives an outlook and presents topic-related questions that build the basis for future research.

Finally, a series of appendices provide valuable additional information. The within-case analysis of the case studies is documented in appendix 1 and the questionnaire is shown in appendix 2.

The complete structure of the thesis is summarised in Figure 2.



**Figure 2: Outline of the thesis**

## 1.5 Conclusions

This chapter illustrated the underlying research problem as well as the generic research questions and objectives of the thesis. In this context it was emphasised that resource allocation decisions are of major importance in the R&D field. It was argued that allocating scarce resources to those R&D projects with the highest value contribution is one of the biggest challenges for technology-intensive companies. Only if they manage their R&D activities in an effective and efficient way they will have a chance to prevail in highly competitive markets.

It was pointed out that there are two main forms of resource allocation, in principle. On the one hand the hierarchical, administrative resource allocation via a central decision-maker or steering committee. On the other hand the market-driven resource allocation via the direct interaction of supply and demand.

Based on some preliminary investigations it was stated that hierarchical allocation modes are predominant in theory and practice. Thus, the central research intention of this work is to investigate if and under which conditions the application of market-driven forms of resource allocation is possible and superior compared to existing hierarchical, administrative forms of resource allocation.

Furthermore, the introduction sorted the research topic ‘internal R&D markets’ into the broader context. It was clarified that an internal R&D market is an alternative organisational concept within the scope of innovation management. In the wider sense the topic can therefore be assigned to the field of ‘Industrial Organisation’.

Moreover, it was shown that in recent years there has been a trend towards a more market-oriented management of companies. However, while many corporate functions, such as logistics, technical services etc., are already organised and managed in a market-like way (e.g. profit center concept), the R&D activities are still handled in a rather hierarchic manner.

The remarks made above illustrate that there is a research need concerning the topic ‘internal R&D markets’. But what exactly is the novelty of the present investigation and what contributions does it make to the state of the art of R&D resource allocation?

As the literature review (chapter 2) and the case studies (chapter 4 and appendix 1) show, the topic ‘internal R&D markets’ is still unexplored. On the one hand there is almost no literature, which is of relevance for the topic. On the other hand the case study research illustrates that most of the investigated companies coordinate their R&D activities by rather hierarchical, administrative structures. The application of market-like elements or internal market mechanisms, however, is not an established standard in R&D. Thus, the present investigation makes fundamental contributions to the existing literature and thereby provides interesting new insights for both the scientific community and practitioners.

In a first step, a new definition for an internal R&D market is formulated, which is based on the reference model 'external markets'. This reference model seems to be adequate for the inquiry since the creation of internal markets can be seen as the attempt to reconstruct elements of external markets inside a company (Lehmann, 2002). The present investigation is therefore concerned with the establishment of 'internal markets' in the true sense of the word. This is a fundamental novelty compared to existing literature in this area.

Moreover, the development and test of a new taxonomy of R&D projects build a further novel aspect of the present investigation. In the centre of attention are the following three project types:

- Research & Technology projects (Type 1)
- Projects for the Development of New Products and Processes (Type 2)
- Projects for the Enhancement of Existing Products and Processes (Type 3)

In this way the study explicitly distinguishes between research activities and development activities. Moreover, the newly developed taxonomy is tested for the first time within the scope of an international survey. Main emphasis has the investigation of project type-specific differences concerning the project characteristics, the R&D organisation, the R&D resource allocation and the allocation result. On the basis of the explored project type-specific differences it is shown for which types of R&D projects the application of market-driven forms of resource allocation is most suitable. Thus, the study adds valuable new insights to the state of the art of R&D resource allocation.

Eventually, based on the theoretical and empirical findings, the thesis presents novel policy recommendations for the design of an internal R&D market. In this context a sophisticated model for the evaluation of alternative forms of resource allocation is developed. On the one hand this model allows companies to evaluate if and for which R&D projects an internal market can be used for the resource allocation in R&D. On the other hand the developed model indicates for which R&D projects a market-driven resource allocation is more effective and/or efficient than a hierarchical one. In this way the model provides crucial support for the tailor-made design of an internal R&D market. Compared to all the other literature of relevance, which is presented in chapter 2, this approach is advanced.

In summary, the findings of this study make principal contributions to the literature on innovation management, respectively, R&D management. On the one hand the present investigation closes the identified research 'lacunae' concerning the topic 'internal R&D markets'. On the other hand it constitutes the base for future research activities in this area.

## 2 Literature review

### 2.1 Introduction and fundamentals

This chapter presents an overview of the literature relevant to the research inquiry. On the one hand the presented literature facilitates the basic understanding of the research topic and provides the theoretical foundation of this work. On the other hand the literature review is essential for the identification of ‘weaknesses’ in previous research and for the formulation of the central research questions and intentions.

Section 2.2 illustrates the state of the art of R&D resource allocation. Main emphasis has the description and explanation of the traditional hierarchical allocation structures. This section is crucial for the basic understanding of this work because it illustrates how the R&D resource allocation processes are organised in most of the companies. Moreover, this section deals with recent developments in this field. It is shown that a trend towards a stronger market-orientation of R&D resource allocation decisions can be identified.

In this context the establishment of internal R&D markets plays an increasingly important role. Thus, section 2.3 gives an overview of the relevant literature concerning the internal market concept. This literature review shows the origin and development of the internal market concept and presents some first definitions that are partly contradictory. In addition, it is shown that the ‘internal market literature’ can be subdivided into two general movements. On the one hand the centralised resource allocation via internal markets and on the other hand the decentralised resource allocation via internal markets. A further sub-section deals with the literature that is concerned with the R&D resource allocation via internal markets.

The theoretical underpinnings of the thesis are presented in section 2.4. Main emphasis has the neoclassical approaches, the property rights theory, the transaction cost theory, the principal agent theory, and the value management approach. Each of these theoretical concepts is shortly introduced and explained before it is scrutinised concerning its contribution to the research. In this way the theoretical concepts provide the base from which the limitations of this work are identified.

Section 2.5 finally presents first conclusions and identifies the research ‘lacunae’. On this basis the central research questions are formulated which reflect the general research intentions of this work.

Before the state of the art of R&D resource allocation is illustrated in the following section, the remainder of this section explains fundamental terms and relationships that are crucial for the general understanding of the present investigation.

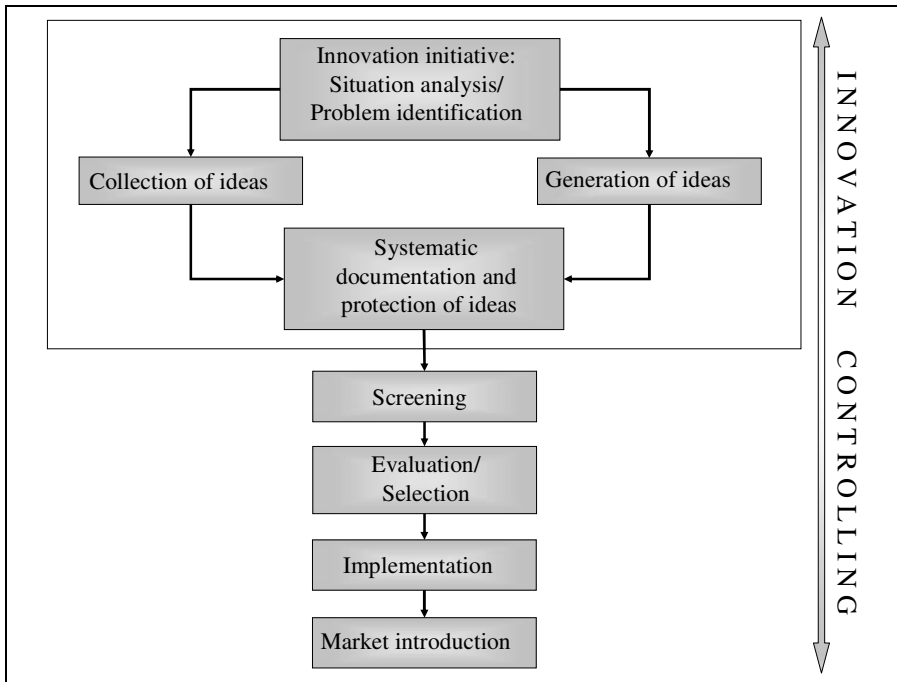
The term **Research & Development (R&D)** is often used as a uniform term in everyday usage. However, this term comprises different kind of tasks (Brockhoff, 1992). In the literature and in practice there exist a multitude of different definitions for this term. Common to all is that they state that R&D activities aim at the acquisition of new knowledge (Specht & Beckmann, 1996). For example, Brockhoff (1992) defines R&D as a combination of production factors that shall enable the extraction of new knowledge. A further wide-spread definition of the OECD (1980) subdivides the term R&D into basic research, applied research, and development.

Brockhoff (1992) describes R&D as activities that are embedded in a comprehensive **innovation process**. In accordance with the definition of the National Science Foundation the term innovation covers the entire process from the germination of an idea through to its widespread application in the market and society. The process starts when a problem is recognised or an idea occurs to someone, all the way to solution of the problem, the procurement of production capacity and placement of the new product on the market.

In the literature manifold approaches concerning the subdivision of innovation processes can be found (Thom, 1980; Brockhoff, 1992; Geschka, 1993; Witt, 1996). The following statement of Boer (1999 p.22) explains the varying nature and the multitude of approaches:

“Research and development typically passes through different stages. Managing projects by stage is a widely accepted and useful practice in industry. Companies have different names for these stages, and the activities found in each stage differ greatly by projects, by company, and by industry. Stages also differ materially by the level of risk, the level of spending, and to a large degree, by the skills of the personnel conducting the R&D.”

Figure 3 illustrates the main stages of the innovation process from the generation of ideas, via the project selection up to the market introduction (following Vahs & Burmester, 1999).



**Figure 3: Innovation process**

Within the scope of innovation processes **R&D resources** must be allocated, respectively, reallocated. In the broadest sense of the word resources comprise manpower, long-term and short-term assets, available technologies, knowledge and funds (Henderson & Quandt, 1983; Varian, 1995). Or in other words, all the staff, equipment, facilities, materials and funding, which are necessary and available for achievement of a project target, constitutes the resources of a project.

Increasing the amount of resources employed can, in certain cases, bring about a substantial reduction in the duration of a project. By the same token, a shortage of resources can prevent timely achievement of project targets.

The internal **resource allocation** is concerned with the distribution of these scarce resources on organisational units and/or on projects. Beside this rather broad definition there also exist more specific definitions that exclusively focus on the allocation of funds (Milgrom & Roberts, 1992).

In general, the following two forms of resource allocation can be distinguished: On the one hand hierarchical, administrative forms of resource allocation (see section 2.2.1), and on the other hand market-driven forms of resource allocation (see sections 2.3, 2.4 and 3.2). The thesis in hand focuses exclusively on the favourability of a market-driven allocation of R&D resources.

Beside the allocation of resources on R&D units or locations the allocation on R&D projects plays an increasingly important role. Thus, the thesis is based on the understanding that resource allocation is concerned with the allocation of scarce resources, respectively, budgets on R&D projects.

In the literature there does not exist a general definition of the term '**budget**' (Heiser, 1964; Koch, 1976a; Dambrowski, 1986). Heiser (1964) defines the budget as a complete presentation of the planned, in monetary terms expressed tasks of an enterprise in a certain planning period. Thus, the budget can be interpreted as the monetary shaping of an operative plan (Koch, 1976b). On top of this, budgets are often used as steering instruments; this means that budgets serve as guidelines.

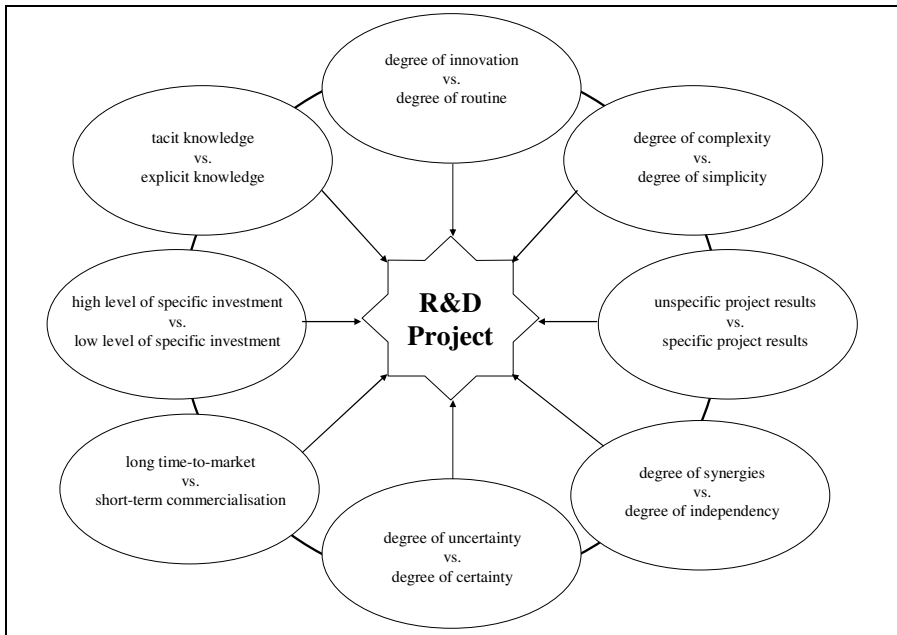
The budgets can be determined either top-down or bottom-up. In practice often a mix of top-down and bottom-up elements is applied within the scope of the budgeting processes (Horváth, 1990; Specht & Beckmann, 1996; Laux & Liermann, 1997). In the R&D context Twiss (1994 p.50) mentions the following possibilities for determining R&D budgets:

- interfirm comparisons,
- a fixed relationship to turnover,
- a fixed relationship to profits,
- reference to previous levels of expenditure,
- costing of an agreed programme,
- internal customer-contractor relationship.

Particularly the last point can be considered as a market-like element and is described as a so-called 'direct assignment' in the R&D practice. In the context of the present investigation the allocation of R&D resources on R&D projects and/or on R&D project types is synonymous with the allocation of the corresponding budgets.

**R&D projects** aim at the study of new technologies and methods or the development and/or enhancement of products or processes. Main characteristics of projects are a specified goal, fixed project duration, uncertainty and risk as well as a limited budget (Schmelzer, 1986; Gomez & Zimmermann, 1993). Against the setting of these characteristics a set of dimensions can be used for the description and/or classification of R&D projects.

Figure 4 gives an overview of the range of some of the most relevant dimensions.



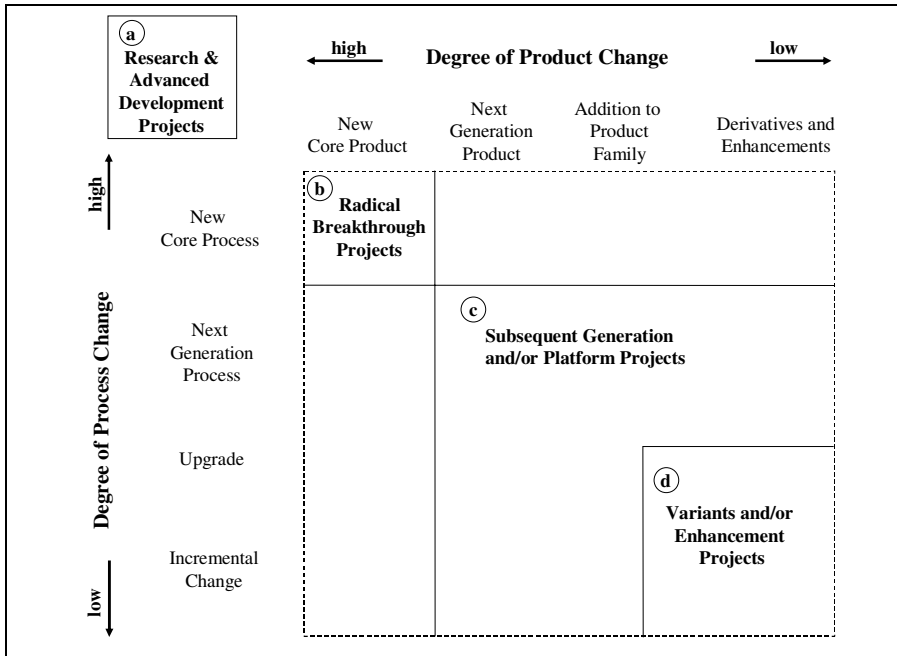
**Figure 4: Dimensions of R&D projects**

- The dimension ‘degree of innovation vs. degree of routine’ describes to what extent new organisational flows, new procedures or new knowledge for the implementation of the projects are needed.
- ‘Degree of complexity vs. degree of simplicity’ refers to the problems that occur due to the complexity of tasks (e.g. problems of coordination, structuring, or transparency).
- The ‘specificity of project results’ describes to what extent the project results can be used by more than one internal client (e.g. different divisions/business units make use of the same project result, or a project result is only useful for one internal client).
- The dimension ‘degree of synergies vs. degree of independency’ describes to what extent the respective project has a technological ‘overlap’ to other R&D projects (e.g. several projects are based on the same basic technology).
- The dimension ‘degree of uncertainty vs. degree of certainty’ describes to what extent project objectives, resource needs (man hours etc.) can be determined before the project actually begins.
- The ‘time-to-market’ describes the time period between the start of a project and the dissemination of the project’s results.

- The dimension ‘high level of specific investment vs. low level of specific investment’ refers to the expenditures for specific infrastructure (e.g. specific laboratory equipment) relative to the overall project expenditures.
- The dimension ‘tacit vs. explicit knowledge’ describes the kind of knowledge needed for the implementation of a project (e.g. the needed knowledge can be made explicit in form of written handbooks, or the knowledge is based on experiences and can hardly be expressed in words).

In the literature different approaches for the categorisation of **R&D project types** are suggested. A traditional approach is the distinction between radical and incremental innovations (Zaltmann & Duncan, 1973). Blake (1978), for example, distinguishes between minor-change and major-change projects. A similar approach is presented by Nippa & Reichwald (1990). Depending on different characteristics, such as the degree of complexity, newness, variability and structuring they differentiate between new development projects and enhancement projects.

Wheelwright & Clark (1992) made a further very fundamental and widespread classification of R&D projects. They differentiate, as a function of the degree of the product and/or process change, the following four project types (Wheelwright & Clark, 1992 p.92): Research & Advanced Development Projects, Radical Breakthrough Projects, Subsequent Generations or Platform Projects, and Variants and/or Enhancement Projects. Figure 5 illustrates the typology of R&D projects following Wheelwright & Clark (1992).



**Figure 5: Typology of R&D projects (following Wheelwright & Clark, 1992)**

Each type of project plays a different role in the firm's portfolio and makes a different contribution for stabilising and sustaining the competitive ability of the firm. Likewise, the different project types need a different share and mix of resources and generate very different results (Wheelwright & Clark, 1992).

Concerning the topic 'internal R&D markets' (see sections 2.3, 2.4 and 3.2), it is also necessary to work out the characteristics of the **profit center concept**. In huge multinational groups the business is organised in form of divisions and/or business units. Furthermore, the operations are segmented into products, product groups, regions and customers. Depending on whether the divisions and/or business units are organised as cost centers, investment centers or profit centers, they can act more or less independently (Picot, Dietl & Franck, 2002):

- In case the divisions and/or business units are organised as cost centers they have no influence on the nature, quantity and price of the results that must be produced. Rather they are responsible to produce the requested services in the desired quality and with the least possible costs.
- If the divisions and/or business units are organised as profit centers, they are not only responsible for costs but also for profits. Thus, profit centers can make independent decisions concerning the product portfolio and the corresponding usage of resources. In particular they can make independent decisions on production quantities and prices.
- In the case of an investment center organisation the respective units are additionally responsible for capital expenditures.

Within the treatment of internal markets the profit center concept is particularly important, since this concept most strongly reflects the characteristics of the interactions taking place on external markets (Lehmann, 2002). Occasionally the establishment of profit centers is seen as an indispensable condition for the introduction of internal markets (Eccles & White, 1986; Frese, 1998a). This way of thinking leads to the fact that the enterprise is subdivided into relatively independent operating units that are profit responsible and thus have to be coordinated according to the overall enterprise's goals (Picot, Dietl & Franck, 2002).

The profit center organisation also requires that all factors that determine profits, such as costs, quality and price, can be influenced by measures of the respective units. Internal exchanges between the profit centers are settled by transfer prices (Milgrom & Roberts, 1992; Krueger, 1997).

There are several advantages that can be realised through a profit center organisation. On the one hand the built profit centers are closer to the markets and customers and can thus react more flexible and faster to potential changes. On the other hand the motivation of the single units can be increased, since they are allowed to appropriate their earned profits (Krueger, 1997).

Against the setting of the remarks made above the profit center organisation is an essential prerequisite for the establishment of internal markets. However, before the topic 'internal markets' can be discussed in more detail in the context of R&D, the state of the art of R&D resource allocation has to be explained in the following section.

## **2.2 State of the art of R&D resource allocation**

### **2.2.1 Hierarchical allocation**

#### **2.2.1.1 Organisational structure of R&D**

Fundamentally, the following three main forms of the organisation of R&D activities can be distinguished (Specht & Beckmann, 1996; Chiesa 2001):

- completely decentralised R&D organisation
- both centralised and decentralised R&D organisation
- completely centralised R&D organisation

The completely centralised and the completely decentralised R&D organisation are rarely found in practice. Rather there is an organisational separation of research activities on the one hand and development activities on the other hand (see section 4.3).

Due to the lack of divisibility of research activities the research function is often centralised. In this way 'economies of scale'<sup>3</sup> as well as 'economies of scope'<sup>4</sup> can be realised. However, the development activities are predominantly conducted by the respective development units of the decentralised divisions and/or business units that are profit centers. Thus, in huge multinational groups the R&D activities are separated into the research function and the development function.

This is especially the case if there is a central corporate research unit. In this unit mainly Research & Technology (R&T) projects are conducted. Some of these R&T projects aim at exploring new businesses and markets, but the predominant part of these projects aim at existing businesses and markets. The latter are often assigned directly by the divisions and/or business units. However, depending upon the distribution of the competencies it can also occur that R&T projects are conducted by co-workers from the divisional R&D units.

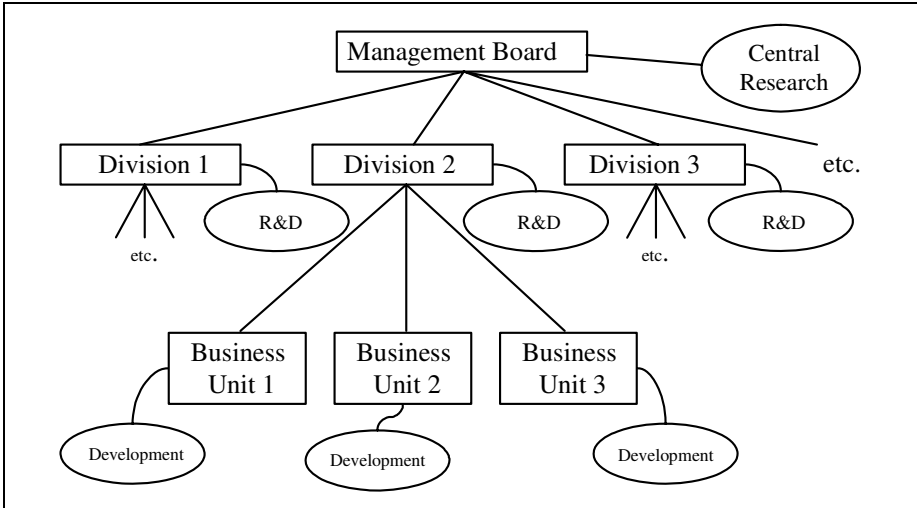
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<sup>3</sup> "The reduction in average cost that is achievable when a single product is made in large quantities." (Milgrom & Roberts, 1992 p.598).

<sup>4</sup> "The reduction in total cost that is achievable when a group of products are all made by a single firm, rather than being made in the same amounts by a set of independent firms." (Milgrom & Roberts, 1992 p.598).

Projects for the development of new products and processes are normally conducted within the divisional R&D units. In very technology-intensive and strongly diversified firms each business unit possesses its own development unit. Beside new development projects these development units also deal with projects for the enhancement of existing products and processes.

Figure 6 illustrates the most complex R&D organisation from the case studies in a simplified form (see chapter 4 and appendix 1).

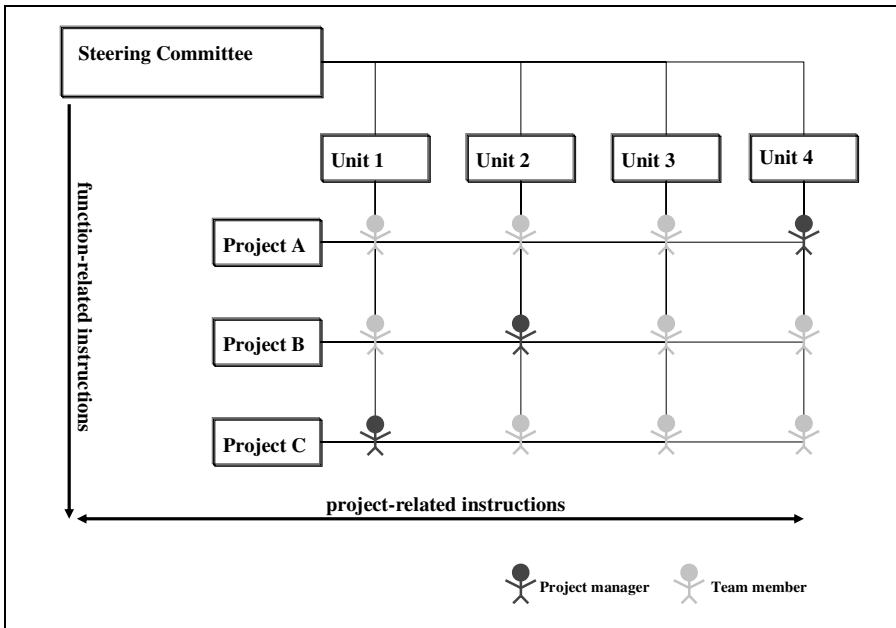


**Figure 6: Organisational structure of R&D**

### 2.2.1.2 *Decision-maker and/or decision-committees and R&D project organisation*

Steering committees are usually the main decision-makers within the context of R&D project portfolio management (Twiss, 1994; Boer, 1999; Völker, 2000). These committees consist of experts from different functions, such as R&D, production, marketing etc. The steering committees decide on the delegation of tasks, competencies and responsibilities. In R&D contexts this means that not the committees have to implement R&D projects, but they have to instruct certain project managers and their teams to do so.

Figure 7 shows the usual matrix-structure of the R&D project organisation.



**Figure 7: R&D project organisation**

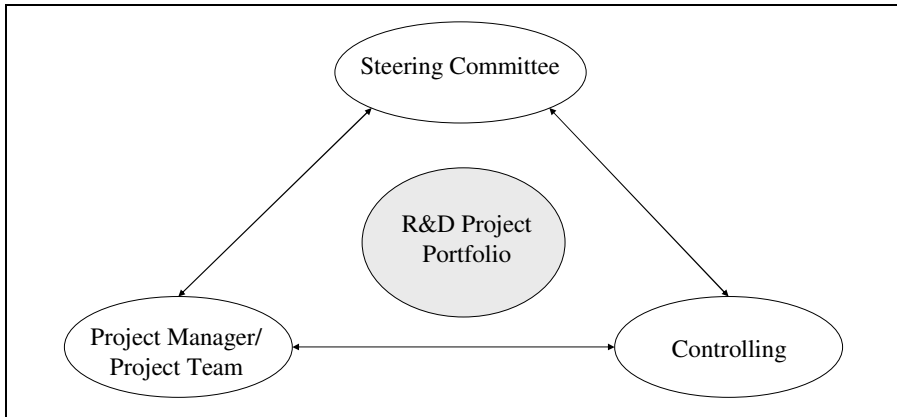
The manager of each project is selected and appointed with the joint agreement of the units concerned. He directs project planning, requests the required resources and is then responsible for ensuring that the project is implemented efficiently within the set timescale. Thus, the project manager has the competence to decide on the distribution and assignment of subprojects (WHAT) and dates (WHEN). The heads of the line functions decide on the use of resources (HOW) and have the authority to issue directives to the respective co-workers (WHO) (see Twiss, 1994; Specht & Beckmann 1996; Boer, 1999).

Within the scope of a kick-off meeting the project manager and the project team agree on the project target (together with the project initiator), plan the work structure, interfaces and milestones. This often takes place in tight cooperation with the competent controlling unit.

During the implementation of the project regular project meetings are held to discuss the progress made and how to proceed further. After these meetings a project progression report is sent to the relevant steering committees. In the case of large, complex, time-consuming or very costly projects, it may be useful and worthwhile to involve an independent controlling function (achievement of targets, milestone trend analysis, resource availability in multi-project situations, target/ performance analyses).

The task of the project manager and the project team terminates when the project target is reached and the final report is written. The end of a project is, for example, characterised by the passing on of a manufacturing process to production

or the transfer of know-how obtained in the course of work on the project to the relevant line function or, if this is not possible, by an unequivocal agreement between the units concerned. Figure 8 illustrates the teamwork of the involved parties during the implementation of projects.



**Figure 8: Teamwork within the scope of R&D project portfolio management**

For the improvement of the project prioritisation and management many companies have developed so-called stage-gate-models. Such models structure investment decisions concerning the R&D projects into single ‘stages’ in order to minimise potential risks. In addition to this, ‘gates’ are defined, at which the respective decision-makers have to take so-called ‘go/no-go’ decisions. Exemplarily, the ‘ABB Gate Model’ is shown in appendix 1.

### 2.2.1.3 *The hierarchical decision process*

As described in section 2.2.1.2, the ‘pure’ hierarchy is first of all characterised by a central decision-maker and/or committee. They determine the nature and quantities of the products and services that shall be produced. Correspondingly, they allocate the required budgets and resources.

The hierarchical R&D resource allocation process comprises several stages, such as (Twiss, 1994; Boer, 1999; Chiesa, 2001):

- the generation of new ideas in form of projects,
- the procurement and analysis of relevant information,
- the criteria-based project selection,
- the allocation and/or reallocation of resources,
- the development of marketable products, and
- finally the introduction of these products in the markets.

The development process of Syngenta, which is shown in section 4.4, is exemplary for the hierarchical organisation of innovation processes. In the literature the following main weaknesses of hierarchical decision processes can be identified (Leibenstein, 1987; Fisher, Frederickson & Pepper, 2002):

- long communication and decision procedures,
- decision-makers have lack of information, and
- opportunistic behaviour due to information asymmetries.

In the following section the main decision instruments for the evaluation of R&D projects are explained.

#### **2.2.1.4 Decision instruments**

In order to select the most valuable R&D projects and thus to efficiently use the scarce resources several decision instruments for the evaluation of competing projects are applied (Boer, 1999; Völker, 2000).

The importance of R&D project evaluation is expressed in the following statement of Twiss (1994 p.123):

“If the productivity of research is to be increased, then project selection, budgeting, and control must be placed on a more logical and scientific foundation, and not left entirely to the hunches, intuition, and guesses of individuals and committees. This does not mean that management will be absolved from all planning responsibility; research is the antithesis of certainty, and all that formal systems can do is to increase the ratio of objective to subjective criteria on which plans and decisions are made.”

The main objective of all evaluation efforts is to select those projects that contribute the highest value to the enterprise (Foster, 1986). A broad range of instruments for the evaluation of R&D projects can be found in practice (see appendix 1). The following methods are most frequently applied in practice in order to make allocation and/or reallocation decisions:

- Net Present Value (NPV) Method,
- Decision Tree Analysis (DTA), and
- Scoring approaches.

The **Net Present Value Method** is the main evaluation method in the R&D field. Applying this method helps to evaluate alternative projects objectively and unbiased from subjective and emotional influences (Copeland, Koller & Murrin, 1990; Spremann, 1996).

In a first step, the project-related turnover is estimated based on a marketing plan (potential customers, quantities, prices etc). In a second step, the corresponding costs have to be calculated. This requires a close cooperation between the R&D and the marketing function. They determine milestones, required resources and activities based on the development plan. Based on these first two steps the yearly free cash flows can subsequently be defined. The free cash flows will then be discounted with the average capital costs that are calculated by using the Weighted Average Cost of Capital Method (Boer, 1999). The resulting NPV allows the decision-maker to objectively compare alternative projects (see section 2.4.6).

In this context also liquidity aspects must be taken into consideration (Völker, 2000). This is underpinned by the following statement of Twiss (1994 p.146): *“The main expenditures incurred before a new product or process begins to earn a return on its investment consist of R&D costs including prototype or pilot plant construction, capital investment in manufacturing plant, and initial marketing costs.”*

Since R&D projects are fraught with risks concerning future developments, it is not sufficient to have only one scenario for each project. Rather multiple scenarios are needed for a realistic project evaluation. In this context the application of the **Decision Tree Analysis** is a helpful instrument. *“The decision tree exercise contains two critical lessons. First, it highlights the value of being able to terminate a project at each point in its development. This substantially reduces cost and risk. Second, it highlights the distribution of value in various possible project outcomes, in particular, the concentration of value in upside cases.”* (Boer, 1999 p.291).

The DTA comprises the establishment of a decision tree with different scenarios, the definition of the financial implications of each scenario, and the determination of the project value by adding the weighted financial figures.

Figure 9 illustrates the functioning of the DTA.

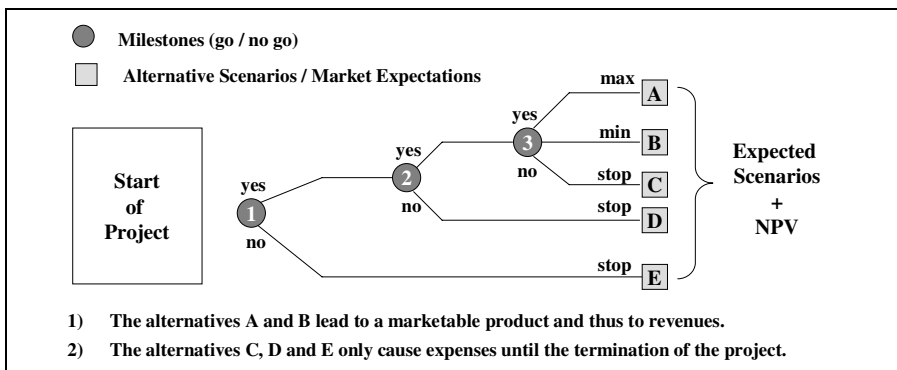


Figure 9: Decision Tree Analysis

In this context it is important to be aware of the fact that R&D projects not only have 'direct' values but also 'indirect' values, so-called options (Cox, Ross & Rubinstein, 1979; Kester, 1986; Brealey & Myers, 1991). R&T projects, for example, often explore first technological know-how that may be useful for future projects. So, if one may wish to measure the value of such a project all potential implications must be taken into consideration. In general, it may be said: The total value of a R&D project is made up of the NPV from the immediate project results and the corresponding option values.

In cases where a monetary evaluation of a R&D project is only hardly possible often so-called **scoring approaches** are applied. This is, for example, the case by projects that deal with 'emerging technologies' (Brown, 1997). In these cases markets and/or products cannot be clearly defined in advance. Thus, the application of scoring approaches appears to be suitable in order to measure the attractiveness of a technology.

The most common scoring criteria in this context are (Pfeiffer, 1982; Brockhoff, 1994):

- **Applicability:** Is the new technology applicable in many fields or is its application restricted to certain niche markets?
- **Degree of ripeness:** Is it about a 'young' technology, which is in the research stage? Or is the technology well known and there are no further developments expected?
- **Competitive situation:** Are there many companies that have mastered the new technology, so that it makes no sense to build up competencies in this field?
- **Patentability:** Can further developments of the new technology be protected through patents or are there any restrictive patents of competitors that prevent this protection?

After this concise description of the main characteristics of the hierarchical R&D resource allocation, the following section now deals with recent developments in the field of R&D resource allocation.

### 2.2.2 Recent developments

The previously described hierarchical decision structures, processes and instruments are established standards in R&D practice (see chapter 4 and appendix 1). However, different trends influence in principle the development towards more market-driven forms of resource allocation. The most remarkable is a stronger market-orientation of innovation activities, which is shown by an increasing number of R&D cooperations (Zedtwitz & Gassmann, 2002).

In literature there is unanimous agreement that cooperations are a form of organisation that lies between 'Hierarchy' and 'Market' (Bronder & Protzl, 2002; Rotering, 1993). But there is no uniform definition of the term 'cooperation'; this

can be explained by the fact that there are a multitude of different cooperation forms (Plaßmann, 1974; Marwell & Schmitt, 1975; Emmerich, 1988).

However, the different authors take the view that cooperations imply a conscious and mutual dependency of the cooperation partners. From that point of view cooperations are characterised by a mix of characteristic features of the coordination through markets on the one hand and the coordination through hierarchical structures on the other hand.

In contrast to the 'pure' market coordination, cooperations can be understood as a consciously and explicitly agreed teamwork between companies. The difference to the hierarchical coordination results from the fact that the agreed teamwork can be unilaterally cancelled at any time (Specht & Beckmann, 1996).

Due to the fact that companies have concentrated their businesses according to their core competencies (Prahalad & Hamel, 1991), nowadays they have the possibility to act much better, faster and cheaper than their competitors. In this context it is thus advisable to concentrate internal R&D resources on such R&D projects, on which the own core competencies can be used (Plinke & Kleinaltenkamp, 1990; Venkatesan, 1993).

However, such behaviour leads to the fact that R&D cooperations are getting more and more important, since the companies either have to purchase missing components or technologies in form of patents and/or licences or they undertake their own R&D activities together with cooperation partners (Ohmae, 1989).

In R&D contexts cooperations most often occur in form of network organisations and/or R&D networks (Specht & Beckmann, 1996; see also Mitchell, 1969; Tichy, Tushman & Fombrun, 1979; Alba, 1982; Lincoln, 1982). Networks can be established either between companies or within an enterprise. Whereas networks between companies have been broadly discussed in literature, the establishment of internal networks have become the focus of recent publications (Sydow, 1992; Kuemmerle, 1997; Sydow, 2001).

This trend is also identifiable in the R&D field, where an increasing number of technology-intensive groups break away from traditional hierarchical organisation structures and turn towards the establishment of global R&D networks in order to coordinate their international R&D activities (Kuemmerle, 1997).

This development is due to the following two reasons:

- On the one hand the sources of new knowledge are globally dispersed. To internalise this knowledge and thus to generate new research results, companies are forced to be locally present in the respective research communities (Miller & Morris, 1999).
- On the other hand the companies are faced with a global competition. In such a competitive environment it is getting more and more important to reduce the time-to-market. But, this is only possible with decentralised local R&D units (Kuemmerle, 1997).

In summary it may be said that recent developments in the R&D field indicate and support a stronger market-orientation of innovation activities, in principle. As the interviews with practitioners showed, this is particularly true for the organisation of R&D resource allocation processes. The Head of Research at BASF, for example, demands a “*market-oriented innovation process*” (Peitz, 2002 p.2) and thus emphasises the increasing importance of markets and customers within the scope of R&D resource allocation.

According to the objectives of the thesis in hand it shall now be investigated if and under which conditions the establishment of internal R&D markets can be an efficient alternative to traditional hierarchical resource allocation processes. Therefore, on the one hand the relevant literature concerning the topic ‘internal markets’ has to be analysed (section 2.3) and on the other hand the topic-relevant theoretical concepts have to be scrutinised with regard to the underlying research questions (section 2.4).

## 2.3 New trend: Internal markets

### 2.3.1 History of the internal market concept and definitions

The first publications that are concerned about the possibilities and limits of internal market mechanisms go back to the mid-20<sup>th</sup> century. Schmalenbach (1948) paved the way for the theoretical analysis of internal markets. Some years later Dean (1955 p.67-8) pleaded for the consequent use of market mechanisms within an enterprise:

“The modern integrated, multiple-product firm functions best if it is made into a sort of miniature of the competitive, free-enterprise economic system. The firm should be composed of independent operating units that act like economic entities, free to trade outside the company as well as inside. Each such entity or profit center will, in seeking to maximise its own profits, do what will also maximise the profits of the entire company, just as individual firms in a private-enterprise society, by seeking their selfish advancement, generate the high productivity and well-being of a competitive economy. [...] The underlying requisite for profit center controls is competitive prices negotiated in arm’s length bargaining by division managers ...”

In the early nineties the discussion of the internal market concept had a revival, which was mainly attributed to the collapse of the economies in Eastern Europe. This breakdown revealed the weaknesses of the planned economy system. Furthermore, a change of heart took place concerning the discussion of ‘Market versus Hierarchy’. Instead of ‘Market or Hierarchy’ the motto was: ‘Market into Hierarchy’. This new way of thinking was based on the assumption that market

elements can be, in principle, integrated in hierarchical dominated structures (Lehmann, 2002).

These developments were accompanied by huge restructuring efforts of companies. Traditional centralistic and hierarchical structures were replaced by flexible, decentralised structures. This trend was reflected by the establishment of profit center organisations.

The functioning of this market-like form of organisation is as follows (Halal, Geranmayeh & Pourdehnad, 1993): Rather than providing budgets directly to internal selling centers, budgets are given to the operating units to purchase services or products either from internal or external suppliers. Internal suppliers have the freedom to sell their services or products to external customers as well as internal ones. Finally, high-level management retains the right to overrule any external transaction for strategic reasons.

Despite of a large number of reports that dealt with successful market-oriented restructurings of companies, neither in theory nor in practice a uniform understanding of the term 'internal market' has been established. Rather there are numerous definitions that are partly contradictory.

The following two definitions of Halal, Geranmayeh & Pourdehnad (1993) and Eccles & White (1986) shall exemplarily illustrate the range of meanings of the term 'internal market':

“This book, *Internal Markets*, presents a new way of thinking about modern organisations. It is a collection of the pioneering work of notable executives, academics, and consultants who are creating a strikingly different, more powerful perspective of large institutions for a new economic area by the imperatives of information technology. Internal markets are meta structures, or superstructures, that transcend ordinary organisational structures. Rather than being fixed structures, they are systems designed to produce continual, rapid, structural change to manage the unusual demands of today's complex, turbulent world.” (Halal, Geranmayeh & Pourdehnad, 1993 p.4).

“The introduction of cost, revenue and profit measures is the introduction of market concepts. Thus, the multi-profit-center firm is a hierarchy with substantial market characteristics, since the profit centers are modeled after the firms of economic theory. Transfer pricing can be understood in terms of the degrees to which elements of hierarchy and market are contained within the firm.” (Eccles & White, 1986 p.214-5).

The comparison of these two definitions shows the divergent views that still prevail in the scientific community as well as in practice. Beside the definition of Halal, Geranmayeh & Pourdehnad (1993) mentioned above there are some further definitions that are derived from the functioning of external markets.

Klein (1998), for example, describes an internal market as a platform for the exchange of scarce internal resources. Internal suppliers and requestors make their bids on a certain amount of these resources and the made bids are balanced and settled via a pricing mechanism.

Spremann (1998) defines an internal market as the entirety of allocation systems that are used for the allocation of cash flows and non-financial resources on business units and/or projects of an enterprise. Since every resource can be expressed in monetary terms Spremann calls this kind of markets "*internal capital markets*" (Spremann, 2001 p.78). He defines internal capital markets as a form of communication that facilitates the comparison of projects through a communicative competition. This competition creates a consensus concerning the adequate evaluation criteria and thus supports the allocation of resources (co-workers, capital, time) on projects.

Melymuka (2004, p.37) recently cites Thomas W. Malone, professor of management at the Sloan School of Management at Massachusetts Institute of Technology (MIT), as follows:

"He defines an internal market as an arrangement where people inside a single company buy and sell things to each other for money or some kind of internal points. Internal markets are an intriguing way that people throughout a company can exchange much more rapidly and widely in a way that lets lots more people make decisions for themselves instead of just relying on people above them to tell them what to do. Information technology greatly reduces the cost and difficulties of having broad internal markets and therefore makes them more feasible in many more situations than they would have been in the past."

A further very fundamental definition is provided by Lehmann (2002). He describes internal markets as a comprehensive structure of organisational regulations that replicate the elements of the free market system. Thus, the establishment of internal markets can be seen as an attempt to reconstruct elements and principles of the free market economy within an enterprise. Based on this general understanding a conceptual framework (including a definition of an internal R&D market) for the empirical studies has been developed (see section 3.2).

In spite of the fact that in literature there cannot be found a uniform definition of the term 'internal market,' the relevant literature can be subdivided into the following two main groups:

- the literature that deals with the centralised resource allocation via internal markets, and
- the literature that deals with the decentralised resource allocation via internal markets.

### **2.3.2 The centralised resource allocation via internal markets**

In the subsequently cited literature internal (capital) markets are understood as instruments for the top-management to allocate corporate resources to and/or reallocate resources between decentralised divisions. This makes clear that an internal (capital) market, as described in the following sections isn't a market in the real sense of the word, but a hierarchical process to (re)allocate resources within a diversified firm.

In his interpretation of the M-form structure Williamson (1975) was the first who pointed out, that internal markets in diversified firms can allocate capital more efficiently than external markets can, and that they can reduce wasteful investment at lower cost. Fazzari, Hubbard & Petersen (1988) additionally provide an empirical analysis that proves cost advantages of an internal capital allocation.

Donaldson (1984) judges the allocation of resources between competing strategic investment possibilities as the central challenge for the top-management. In this context Stein (1997) explains that internal markets are superior compared to external markets, since the top-management has control over the divisions' assets and thus can engage in 'winner-picking' and 'loser-sticking'. This means that management can reallocate capital from bad performing divisions to better performing divisions (Williamson, 1975; Lamont, 1997; Stein 1997; Shin & Stulz, 1998), which indicates the hierarchical character of such 'internal markets'.

The main advantage of this hierarchical allocation via internal markets, compared to external markets, is the fact that the management is provided with better information than external investors and thus can allocate resources more efficiently (Gertner, Scharfstein & Stein, 1994; Stein, 1997; Hubbard & Palia, 1998). Moreover, Gertner, Scharfstein & Stein (1994) come to the conclusion that internally financed investments bring positive effects because of increased incentives of capital monitoring. On top of this is the fact that specific results of prematurely terminated projects find a better internal further use.

In this context Shin & Stulz (1998) argue that the external market supplies all enterprise units with an equal amount of capital without considering their respective investment possibilities, which has the consequence that the capital isn't used efficiently. This is also confirmed by Porter-Liebeskind (2000). Her comparative analysis of internal and external capital markets is concerned with different statuses of information and investment types. She comes to the result that the internal capital allocation is favourable in case of capital restriction, secrecy of investment activities and specific investments, whose advantages are not recognised by external markets.

Furthermore, it is shown that this kind of internal markets function better in companies that are diversified into related businesses compared to companies that are diversified into non-related businesses (Scharfstein, 1998; Shin & Stulz, 1998; Khanna & Tice 2001). As a result, the top-management can more precisely measure the performance of related divisions, due to lower information asymmetries between the top-managers and the division heads. This in turn reduces the incentives for bad performing divisions to undertake 'influence activities' in order to get a bigger share of the budget (Meyer, Milgrom & Roberts, 1992). These opportunistic influence activities of the division heads are also known as "*rent-seeking behaviour*" (Picot, Dietl & Franck, 2002 p.433; Wulf, 2002 p.2).

Regarding the above-cited publications, it can be summarised that compared with external markets the resource allocation via internal markets brings advantages for companies, due to information and secrecy advantages. However, the literature also mentions some negative aspects of internal markets. For example, it is argued that internal markets from an economical point of view can lead either to an excessive or to an insufficient investment volume. The reasons for this are seen on the one hand in the agency-problem and on the other hand in the so-called investment socialism that leads to suboptimal investment alternatives (Scharfstein, 1998; Shin & Stulz, 1998; Scharfstein & Stein, 2000). As a further reason for the inefficiency of internal markets Rajan & Zingales (2000) mention 'power grabbing' of the involved parties.

Despite the different views of the mentioned authors, a common understanding of internal markets is appropriate to all the cited publications (Porter-Liebeskind, 2000):

- they all define internal markets as a form of hierarchical resource allocation between divisions of diversified firms,
- the source of financing of certain investments is not an external backer but the corporate center, and
- the allocation decision is delegated to an internal central decision-committee.

### **2.3.3 The decentralised resource allocation via internal markets**

In recent years a further direction of research was established, which is concerned with the decentralised resource allocation via internal markets. This research works consider the development that firms more and more select organisational forms which transfer the responsibility for decisions and performance to the individual business units, and thus lead to decentralised organisational structures.

This development went hand in hand with the establishment of so-called profit center organisations. In the center of the discussion stand the neoinstitutionalistic approaches (see sections 2.4.3, 2.4.4, and 2.4.5), i.e. the property rights theory (Furubotn & Pejovic, 1972; Alchian & Demsetz, 1973; Picot, 1981; Barzel, 1989), the transaction cost theory (Coase, 1937; Williamson, 1975; Picot, 1982) and the

principal agent theory (Jensen & Meckling, 1976; Pratt & Zeckhauser, 1985; Spremann, 1990).

Buermeyr (2000), for example, argues that corporate governance is of central importance in terms of arrangement and control of the capital allocation and that it is based on market competition and on the allocation of disposal and control rights. Further it is shown that, with sufficient interest homogeneity between financial backers and the market supervisor, transaction cost advantages can be realised.

The works of Sandbillier (1996) and Klein (1998) as well as the former cited Buermeyr (2000) integrate – additionally to the concept of decentralised resource allocation – electronic information and communication technologies like the Intranet.

Sandbillier (1996) focuses on the question how the required market- and customer-orientation can be achieved in the banking sector. In this context he recommends to establish internal markets in form of electronically platforms and to delegate decision competencies to the decentralised and independent banking units that are close to markets and customers.

Klein (1998), however, is concerned with the analysis and design of an electronically equity market in financial services companies. He concludes that such an internal market leads to a more efficient allocation of funds compared with hierarchical budgeting solutions, which is mainly due to the lower communication and information costs (transaction costs).

The above-cited research papers focus strongly on the integration of market-like elements within the scope of the decentralised resource allocation via internal markets. For example, capital for certain investment projects is allocated via an electronically platform by the interplay of internal suppliers and requestors, which are organised as profit centers.

In summary it may be said that the specified publications differ from those of the centralised resource allocation via internal markets by the following three aspects:

- they focus on the capital allocation on investment projects and not on divisions,
- they examine the forms of resource allocation due to the possibilities of modern information systems, and
- they suggest decentralised market-oriented coordination forms with independently acting divisions/business units.

Based on this understanding more recent publications focus on examples of companies that use internal markets for the coordination of different tasks. Malone (2004), for instance, focuses on how internal markets impact companies. He gives examples of how companies used internal markets, e.g. BP (reduction of greenhouse gas emissions), HP (collecting scattered information), or Intel (allocation of

manufacturing resources). According to Malone the major advantages of internal markets are that they encourage creativity and independence and that they can respond faster to capitalise on an opportunity. Furthermore, he states that internal markets “*provide the right incentives for people to buy and sell according to what they actually think will happen. It is, of course, possible that people might try to manipulate the market, [but] I think it will be easier to enforce trading rules because the senior managers will still have the power to punish those who abuse the internal market.*” (Melymuka, 2004 p.37). However, Malone also sees downsides associated with these decentralised organisational structures, such as the disadvantage in controlling risks and quality.

Malone (2004) argues that the transition from centralised hierarchical organisation structures to decentralised market-based organisation structures is mainly enabled by the fact that electronic technologies allow information to be widely shared at little cost.<sup>5</sup> Given this, people have more information, which they can use to make their own well-informed decisions, appropriate to local circumstances, instead of following orders from above. In this way internal markets increase motivation and creativity of employees, so Malone. Moreover, he argues that internal markets are faster and more flexible than traditional forms of organisation so that they can respond rapidly to arising problems and capitalise on opportunities in an effective and efficient manner.<sup>6</sup>

This is also emphasised by Kent (2005). He mentions the case of Sony Europe which uses internal markets for their human resource planning. These so-called internal markets for talent<sup>7</sup> have identified and redeployed individuals working in inappropriate roles which showed positive results regarding the organisation’s effectiveness and efficiency.

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<sup>5</sup> Melymuka (2004, p.37) cites Malone as follows: “The most important reason they [internal markets] haven’t been used is that the cost of communications and information processing needed for them to work has been prohibitive. Now those costs are falling dramatically with new information technologies.”

<sup>6</sup> To illustrate these advantages Malone (2004, p.113) gives the following example: “If an earthquake disrupts work at a critical factory, for instance, the value of factory capacity will immediately shoot up, and all the other factory managers will be highly motivated to see how they can reconfigure their own schedules to take over some of the extra work. They may have to postpone other scheduled projects, but if the prices in the internal market are more or less accurate, they will know exactly which jobs to do and which should be postponed. These adjustments can occur simultaneously, all over the company, without any single person or group trying to figure them out. The invisible hand of the market coordinates all the separate actions into a single coherent plan.”

<sup>7</sup> Refer to Hamel (1999).

Given the promising advantages of internal markets, Stuart (2005) wonders why internal markets haven't become more common. As the main reasons he identified costs, lack of control, and the reluctance of employees to publicise what they know. Nevertheless, he is convinced that these obstacles can be resolved by using adequate incentive systems, which still need to be developed. Moreover, Stuart provides examples of four companies that have used internal markets to make decisions:

- At BP business unit managers traded greenhouse-gas emissions credits to reduce overall corporate pollution.
- HP had sales team buy and sell futures contracts on potential sales volumes at given prices.
- Eli Lilly asked scientists to trade stocks on six mock drugs to gauge which would be most successful.
- Google lets employees bid play-money on when new products and offices are likely to launch.

Further examples of companies that use internal markets are illustrated by Välikangas & Merlyn (2002). They distinguish between intramarkets, in which all trading of ideas, capital and talent takes place between employees and business units (e.g. Shell, EDS, BP), and extramarkets, which are similar to intramarkets except participation includes selected external partners (e.g. IBM, World Bank).

Given the fact that the economy is becoming more and more knowledge-based and that innovation is a critical source for the success of companies, Malone (2004) suggests that now is the right time to doing research and start experimenting with the innovative concept "internal market". This is exactly the intention of this inquiry which aims at investigating if and under which circumstances the application of internal R&D markets is suitable.

#### **2.3.4 The R&D resource allocation via internal markets**

To date, there is only one article, which is concerned with the topic 'internal markets' in the context of R&D resource allocation. Reger (1999) focuses his research on the question, which mechanisms are suitable for the coordination of international R&D and innovation processes in multinational companies.

In a comparative study with European and Japanese companies he outlines four coordination mechanisms:

- structural,
- hybrid,
- informal, and
- internal markets.

Reger's exploratory study comes to the result that R&D activities in Japanese companies are essentially coordinated via informal mechanisms, while European firms trust more strongly in internal markets. As a basic condition for the functioning of internal markets Reger (1999) calls the existence of a profit center organisation, i.e. the individual organisational units and concomitantly the R&D units must be responsible for their own business performance.

He therefore describes the coordination mechanism internal market by the following three components:

- the organisational units are responsible for their own profits,
- they have autonomy of decision regarding clients and suppliers, and
- there are internal inter-company prices.

Since he states in his study that the R&D units of the companies are organised as cost centers a substantial condition for the operability of an internal market in the real sense of the word is missing, and therefore he calls the internal markets in his study "*quasi-markets*" (Reger, 1999 p.75).

In summary it can be said that the cited literature regarding internal markets is predominantly concerned with the hierarchical, administrative organisation of the internal resource allocation and reallocation processes in a firm. But little is said about establishing real internal markets within an enterprise, respectively, within the R&D resource allocation on single projects. Given this research gap, the present investigation focuses on the allocation of scarce resources on single R&D projects via internal markets.

But, before the analysis of the empirical findings is presented the topic-relevant theoretical concepts are introduced and scrutinised with regard to the central research questions, which are: For which types of R&D projects are market-driven forms of resource allocation a) possible and b) superior compared to hierarchical forms of resource allocation?

## 2.4 Theoretical underpinnings

The following sections present an overview of the basic topic-related theories. According to the scope of the thesis only those theories with a particular relevance to the present investigation are considered. Emphasis has the detailed investigation and critical appraisal of the neoclassical approaches (section 2.4.2), the property rights theory (section 2.4.3), the transaction cost theory (section 2.4.4), the principal agent theory (section 2.4.5), and the value management approach (section 2.4.6).

However, in a first step, section 2.4.1 presents a brief general review of traditional or 'classical' theories of organisation, which provide the basis for the theoretical concepts mentioned above.

## 2.4.1 Contributions of traditional organisation theories

### 2.4.1.1 Overview of traditional organisation theories

Organisations represent highly complex social systems. A number of theories have been formulated in order to understand and explain the nature of organisations and their various manifestations (Scott, 1987; Kieser, 1993b; Picot, Dietl & Franck, 2002).

Max Weber's view of bureaucracy has been considered the only rational form of organisation for a long time, despite the fact that Weber himself acknowledged that it should only be applied to workers with a low level of qualification as highly qualified individuals might perceive bureaucracy as 'iron cage' depriving them of human dignity and responsibility. Theorists soon realised the situational limitations of Weber's bureaucracy model and explored alternative forms of organisation. The most influential traditional theories of organisation include bureaucracy, scientific management, the human-relations approach, behaviourist decision theory and the situational approach.<sup>8</sup> The intention and implications of these theories can only be understood with reference to the historical conditions and philosophical frameworks from which they emerged.

The central idea of Weber's **bureaucracy** model<sup>9</sup> is the concept and process of rationalisation on three levels:

- on the level of institution (calculability and controllability of the problems of the natural and social world through science, technology and organisation),
- on the level of views of the world and belief systems (magical elements are displaced by religious elements, concrete religious ideas are displaced by more abstract ones, and religious ethic loses some of its binding nature),
- on the level of practical everyday life (individual life is increasingly conducted methodically and in accordance with individuals' value systems).

Weber views humans as carriers of bureaucratic tasks. According to Weber, bureaucracy is the most efficient way of coordinating humans towards goals. Furthermore, bureaucracy is the only form of legal domination. In its ideal manifestation, bureaucracy is characterised by a high degree of hierarchy (of offices), extensive paperwork and 'by-the-book' procedures as well as impersonal exercise of power. Moreover, classical principles of organisation deductively add several practice-oriented requirements (e.g. Fayol's single line or line and staff systems) to Weber's catalogue.

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<sup>8</sup> Frese (1992) and Kieser (1993a) provide a detailed discussion of the historical development of theories of organisation.

<sup>9</sup> Proponents: Weber, Fayol. For the history of its beginnings see Fayol (1916), Mill (1948), Hattenhauer (1980), Fritz (1982), Jacoby (1984), Wunder (1986) und Weber (1988).

In this context it has to be noted that organisation is traditionally treated as a closed system, i.e. that situational contexts are discounted. In addition, principles of organisation derived from Weber's theory claim validity and generality without supporting empirical evidence. Socio-emotional considerations have no room in this school of thought. However, to counter the danger of a 'pedantocracy,' Weber calls for a charismatic personality at the top of the organisation (for a fundamental discussion of Weber's model of bureaucracy see Gabriel, 1979; Weber, 1988; Albrow, 1990; Kieser, 1993c).

The theory of **scientific management** (Taylorism<sup>10</sup>) was developed by Fredrick W. Taylor. Taylor extended Weber's notion of rationalisation into the area of work organisation by replacing general principles of organisation with a specific method. His methodological principle experimentation is embedded in a system of strategic design objectives (Taylor, 1911; Ebbinghaus, 1984; Kieser, 1993d):

- separation of manual and intellectual labour,
- workload and incentive,
- selection and adaptation of workers, and
- reconciliation of workforce and management through dominance of experts.

Taylorism is based on a mechanistic view of human nature (machine with disruptions). According to Taylor human labour needs to be fragmented in order to reach the effectiveness of machines. This also applies to relatively skilled labour (functional foremanship). Moreover, work needs to be organised ergonomically, i.e. there must be a match between abilities and task requirements. Furthermore, compensation systems should be performance-based, and reasonable working hours need to be set in order to reduce performance decrements due to tiredness (as was often the case in the 19<sup>th</sup> century).

In this context engineers (not managers!) determine objective design criteria for workplaces by means of scientific experiments (e.g. studies of body movements, selection tests and experimentation with incentive systems). The dominance of experts and scientific methods supposedly leads to harmony between leaders and workers. (A number of principles for efficient management of organisations have been developed on the basis of Taylor's scientific management. Significant contributions came from Gulick & Urwick, 1937; Davis, 1939; Brown, 1945; Mooney, 1947; Dale, 1952; Brech, 1957; Koontz & O'Donnell, 1964; Massie, 1965).

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<sup>10</sup> Proponent: Taylor. For fundamental principles see Taylor (1911).

The **human relations approach**<sup>11</sup> views the working human as socially-motivated 'animal sociale' equipped with certain needs. The establishment of personal relationships is considered a central factor in production (Roethlisberger & Dickson, 1939; Kieser, 1993e). This was evidenced by Mayo's Hawthorne studies that demonstrated that concern for workers leads to better performance. In accordance with these findings, a case is made for a new type of manager. So far personality traits like intelligence, competence, enthusiasm, honesty and fairness were traditionally considered prerequisites of a successful leader. The human relations approach, by contrast, emphasises personal qualities such as 'being worthy of authority,' open-mindedness, readiness to learn from subordinates, openness to criticism and the ability to admit mistakes.

The proponents of the human-relations approach call for relationship-centered leadership of groups and assume that work satisfaction is positively correlated with work performance. However, it should be noted that work satisfaction does not necessarily lead to higher output since it is not oriented towards the organisation's goals. Furthermore, human relations demands 'management by motivation,' which is restricted to intrinsic factors. Moreover, it has to be noted that there is a tendency in human relations to gloss over conflicts in the work environment where solutions would be necessary.<sup>12</sup>

**Behaviourist decision theory**<sup>13</sup> focuses on humans as decision-makers. Research in this framework centered on adaptation to a complex and changing environment, as a means of securing the existence of organisations with emphasis on human limitations and boundaries. Decision theory reformulated the adaptation to environmental conditions as a problem of human (decision-making) behaviour.

The theory therefore rests on assumptions about characteristics of humans relevant to decision processes. So, decision theorists take into account that human capacity for information processing is limited. This implies that although individuals attempt to act rationally, they may fail to do so under specific circum-

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<sup>11</sup> Proponents: Majo, Maslow, McGregor, Herzberg. Cf. Münsterberg (1914), Marr (1924), Maslow (1954), Bendix (1960), Herzberg (1968), Hinrichs (1981), McGregor (1985) and Kieser (1993e).

<sup>12</sup> The human relations movement was accompanied by an enormous growth of the discipline of organisational psychology. The central areas of occupational and organisational psychology are work motivation, work satisfaction, diagnosis and remedy of psychological strain in the work process, leadership, interactions between individuals and work groups, design of workplaces and tools from a psychological perspective, decision-making by individuals and groups, personnel selection, training and conflict management. Cf. Lorsch (1987), Weinert (1987), Frey, Hoyos & Stahlberg (1988), Greif, Holting & Nicholson (1989) and Ulich (1991).

<sup>13</sup> Proponents: Barnard, Simon, March, Cyert. For a fundamental discussion of the behaviourist decision theory see Barnard (1938), March & Simon (1958), Cyert & March (1963) und Simon (1976).

stances. For a fundamental discussion of the notion bounded rationality see Simon (1997).

One of the central assumptions of decision theory is that the readiness of humans to identify with organisations is limited. Organisations in this view do not consist of people, machines, premises etc. but of actions carried out by diverse 'participants' or agents. In this context it has to be distinguished between prescriptive and descriptive decision theory. While prescriptive decision theory sets out how well-structured problems can be solved, descriptive decision theory attempts to explain how badly-structured but well-defined problems are solved in organisational practice.

However, there is as yet no comprehensive theory of human decision-making behaviour. But, behaviourist decision theory integrates selected social theories, especially approaches to motivation, which offer explanations for individuals' decisions. Knowledge of individual decision processes contributes to an understanding of collective decision-making, which in turn yields information for analyses of organisational decision-making.

At this juncture it has to be noted that a hermeneutic approach (which would be essential to an interpretation of the effects of organisational culture on behaviour) is rejected by decision theorists. Organisational structures are not assumed to exert significant influence on the behaviour of individual members.<sup>14</sup>

The **situational approach** (contingency approach) to organisation contrasts with decision theory in that it does not focus on decision processes within the organisation. The central object of investigation in this framework is the structure of organisations (Woodward, 1965; Child, 1970; Staehle, 1973; Pugh & Hickson, 1976; Lammers, 1978; Hickson & McMillan, 1981; Kieser, 1993f).

The situational approach rests on the assumption that organisational structure has a large impact on the efficiency of organisations, but it does not claim that there is a single universally efficient form of organisation. Proponents of the situational approach also consider the external environment a strong influence on organisational structure. Organisational structure again is thought to affect the efficiency of an organisation through the behaviour of its members. It is emphasised that organisations can only be efficient if they adjust their internal structures to changing situations. Central issues in the situational framework are:

- the effects of organisation size on organisational structure,
- the influence of the environment on organisational structure, and
- the impact of production engineering on organisational structure.

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<sup>14</sup> Refer to March & Olsen (1972), March & Olsen (1976), March (1988) and Berger & Bernhard-Mehlich (1993) for discussions of more recent developments of decision theory.

It is, for example, surmised that large organisations require different structures than small organisations, that organisations in a dynamic environment should have a different structure than organisations in static environments, and that organisations of mass production need a different structure than manufactures.

#### 2.4.1.2 *Critical appraisal*

The traditional theories of organisation outlined in the preceding sub-section are essential to an understanding of the development of different forms of organisation, and they form the basis for recent developments in the field of organisational theory and development.

Weber's model of bureaucracy has become highly controversial as bureaucracy is no longer considered efficient or modern. The original strength of the model was to make the actions of individuals within organisations more calculable and transparent. This strength has in fact turned out to be the theory's principal weakness as calculability and transparency come with rigidity and inflexibility as side effects. Bureaucracies can, therefore, only be efficient if the tasks of the organisation are calculable and repetitive. However, the rapidly changing tasks and priorities common to R&D activities require alternative forms of organisation. Some authors suggest that R&D efforts in bureaucratic organisations are often hampered by internal power-struggles between specialists and bureaucrats (Kieser, 1993c).

Rationalisation, the fundamental concept of scientific management, still has great practical appeal. Scientific Management demonstrates that the efficiency of organisations can be increased by maximal division of labour. However, the implicit de-qualification of the workforce limits extreme rationalisation to mass-production. It does not seem conducive to product variability and innovation (R&D operations) (Kieser, 1993d).

Many organisations embraced the human relations approach as a valuable supplement and corrective for Taylorism. The new emphasis on human relationships leads to a fundamental revision of the treatment of workers. Firstly, managers were asked to see workers as humans, and to care about their personal success and well-being. Secondly, incentives (wages, salaries, fairness etc.) were interpreted differently with respect to their motivating effects. This makes it somewhat difficult to pin down 'hard' savings and improvements. Human relations nevertheless illuminate the importance of relationships and adequate compensation systems (Kieser, 1993e). Hence it can be argued that informal collaboration is an important factor for an enterprise's R&D function and thus its ability to innovate and that the design of an adequate compensation and incentive system is equally important for the success of R&D activities.

Behaviourist decision theory represents a crucial addition to the above approaches, which essentially view organisations as closed systems. Decision theory opened up a perspective on the interdependencies of and interactions between environment and organisation. It is assumed that external factors exert a constant pressure on organisations to adapt in order to remain successful. Decision theorists

propose that even though organisations may depend on their environment they can actively modify it or select a segment of the environment in which they wish to operate. In this way decision theory differs fundamentally from scientific management and the human-relations approach in that it considers members of the organisation part of the environment.

However, decision theory discounts organisational structures as important driving forces behind the behaviour of organisation members (Berger & Bernhard-Mehlich, 1993). This view does not appear tenable, especially with respect to R&D activities. Such activities call for flexible forms of organisation, which facilitate innovation by giving employees room for experimentation and creativity.

In contrast to behaviourist decision theory, the central assumption of the situational approach is that the architecture of an organisation has a strong effect on its efficiency in as much as structure affects the behaviour of organisation members. The theory furthermore holds that organisations need to adjust their structures to their respective situations in order to remain efficient (Kieser, 1993f). This is particularly important for the R&D functions of multinational groups. They operate in highly dynamic environments (changing customer requirements, technological advances, changes in legislation etc.), which implies that R&D needs highly flexible organisational structures (e.g. internal R&D markets, R&D networks etc.).

In conclusion, the traditional organisation theories do not allow making explicit statements with regard to the research topic. However, they are essential for the general understanding of different organisation forms, and they provide the basis for the subsequently introduced theories of relevance.

## **2.4.2 Contributions of the neoclassical approaches**

### **2.4.2.1 Foundations of the theory**

In the twentieth century there has been a school of thought in economics that emphasised the importance of ‘resource allocation’. This school of thought is called ‘neoclassical economics,’ and the ‘neo’ means that they differ in important ways from the previous ‘classical economists’ (e.g. Smith, 1776). In summary it may be said that neoclassical economics view economics as the study of the ‘allocation of resources’. Thus, the study of neoclassical approaches is important from the point of view of this thesis.

The framework of neoclassical economics can be summarised as follows (Milgrom & Roberts, 1992; Pindyck & Rubinfeld, 2001; Picot, Dietl & Franck, 2002):

- Buyers attempt to maximise their gains from getting goods. They do this by increasing their purchases of a good until what they gain from an extra unit is just balanced by what they have to give up to obtain it. In this way they maximise ‘utility’ (the satisfaction associated with the consumption of goods

and services). Likewise, individuals provide labour to firms that wish to employ them. Thereby they balance the gains from offering the marginal unit of their services (the wage they would receive) with the disutility of labour itself (the loss of leisure). Individuals make choices at the margin. This in turn results in a theory of demand for goods, and supply of productive factors.

- Similarly, producers attempt to produce units of a good so that the cost of producing the incremental or marginal unit is just balanced by the revenue it generates. In this way they maximise profits. Firms also hire employees up to the point that the cost of the additional hire is just balanced by the value of output that the additional employee would produce.

The neoclassical approaches thus involve economic ‘agents’ (households or firms), that try to optimise their own utility, and are subject to all relevant constraints. Value is linked to unlimited desires and wants colliding with constraints, or scarcity. The resulting tensions and decision problems are worked out in markets. In this context prices are the signals that tell households and firms whether their conflicting desires can be reconciled (Milgrom & Roberts, 1992).

The central notion of the neoclassical approaches, which is of relevance to the present investigation, is that of a competitive market. Neoclassicism aims to explain the allocation problem, i.e. the question which laws govern the distribution of scarce resources among alternative uses. In this context the neoclassical model of market shows that the structure of supply adapts to demand via the mechanism of relative prices, which leads to optimal allocation of resources. A so-called ‘invisible-hand process’ thus matches production to demand (Smith, 1776; Milgrom & Roberts, 1992). Condition for the successful matching is the free market or a market economy in a broader view. The neoclassical model of market assumes that:

- the goods are homogenous,
- demand and supply occur simultaneously,
- the market is fully transparent,
- participants have an infinitely small reaction time, and
- suppliers and demanders have no preferences.

In addition, neoclassicism supposes that market participants show individual behaviour and have subjective optimisation targets. How much a demander is prepared to pay for a good therefore depends on his individual optimisation target (Shepherd, 1990; Fritsch, Wein & Ewers, 2001).

Neoclassicist theory distinguishes two ideal types of markets:

- factor markets, and
- goods markets.

Suppliers of factors of production and enterprises as demanders interact in factor markets, whereas goods markets are populated by suppliers of finished products and households as consumers. Prices in competitive markets with many participants are not determined by individuals, but by the overall process of market interaction or ‘invisible hand’.

A specific household theory on the one hand addresses the question how a consumer chooses among different goods and different quantities of goods at given prices. Production theory on the other hand investigates how a producer chooses the goods to be produced, their quantities and the factors of production and technologies needed at given prices.

Neoclassical theory shows that competition transforms the decentralised decisions of individual participants into an efficient overall result, while restrictions of competition and exercise of market power impedes an efficient overall result of allocation processes (Picot, Dietl & Franck, 2002).

#### **2.4.2.2 Assumptions and conditions**

The fundamental neoclassicist model describes a state of perfect competition. The following section discusses the assumptions underlying this idealised state. One of the essential suppositions is the objective rationality of the market participants. It is assumed that participants can consider and plan all current and future market developments at no cost (perfect information), and that they act to maximise utility (consumers) or profit (producers).

Concerning the environment, the model of perfect competition makes the following central assumptions (Shepherd, 1990; Fritsch, Wein & Ewers, 2001):

- atomistic market structure, i.e. many small producers and consumers with small market shares are facing each other,
- homogeneous goods,
- transparency of the market, i.e. cost-free, immediate and complete availability of relevant information,
- stability of preferences, technologies and remaining environmental factors,
- unlimited divisibility of all goods and factors of production,
- no unwanted exchanges due to external effects (e.g. air pollution by production facility),
- perfect mobility of all factors of production and goods, and
- timeless (immediate) adjustment processes.

A further assumption is that the neoclassical production function normally has concave shape. Increasing expenditure of a single factor of production at constant expenditures of the remaining factors leads to an increase in output, but from a certain point onwards only at the cost of decreasing marginal rates. Marginal costs therefore rise with each additional unit of output (Picot, Dietl & Franck, 2002).

#### **2.4.2.3 *Internal efficiency and allocative efficiency as combined efficiency criterion***

Neoclassicist theorists discuss different criteria of advantage as means of assessing the results of market processes (Shepherd, 1990). Efficiency is considered a central criterion for the assessment of the economic result of a market process. To act efficiently means to achieve the best result or a defined goal with the lowest possible expenditure of (limited) resources.

Competition theory distinguishes two subcriteria of efficiency:

- internal efficiency (X-efficiency), and
- allocative efficiency.

Internal efficiency relates to internal processes of value creation in an enterprise (Leibenstein, 1966). Enterprises are considered efficient if they produce a certain level of output at the lowest cost. Deviations from X-efficiency are termed slack.

Allocative efficiency is divided into production-economical total efficiency, efficient production structure and pareto-optimal distribution. Production-economical total efficiency requires the entire production sector to produce an efficient output vector<sup>15</sup> from a given set of factors. There must be no redistribution of factors of production to units of production which generates an output vector that contains at least the same quantity of all goods in the original vector and a larger quantity of one good. Unlike production-economical total efficiency, the efficiency metrics efficient production structure and pareto-optimal distribution include consumer preferences. In addition to production-economical total efficiency it is assumed that from among the efficient output vectors a vector is chosen such that every possible redistribution, which increases the utility for one consumer, automatically reduces it for another. This state is referred to as pareto-optimal (Milgrom & Roberts, 1992; Picot, Dietl & Franck, 2002).

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<sup>15</sup> The output vector aggregates the quantities of all production units for each product.

#### 2.4.2.4 *Critical appraisal*

First of all it has to be noted that neoclassical approaches are based on some unrealistic assumptions. However, with regard to the research topic ‘internal R&D markets’ neoclassical theory makes some fundamental contributions. On the one hand it explains that market interactions lead to efficient outcomes and on the other hand it shows that market failures can occur in certain situations. On this basis it can be evaluated for which types of R&D projects market-driven forms of resource allocation are most suitable.

Employing the neoclassical model, microeconomics has proven that every ‘competitive equilibrium’ in a market is pareto-optimal, given perfect competition. It is not possible to strengthen the position of one participant without weakening the position of another in such markets (Milgrom & Roberts, 1992; Pindyck & Rubinfeld, 2001). Another important feature of perfect markets in the context of the present investigation is that participants incur no costs for their use. This is clearly an unrealistic assumption given that economic entities are frequently less than perfectly informed or transactions do not take place for the simple reason that an entity or individual has no knowledge of the existence of a product or supplier. Personal preferences are often present in transactions or there exist spatial or temporal barriers to market entry. Every deviation from the ideal conditions presented in section 2.4.2.2 leads to an imperfect market and causes transaction costs (see section 2.4.4).

Moreover, market participants have no room for manoeuvre under the idealised conditions of perfect competition, and they are forced to adjust quantities. If one relaxes individual assumptions and, for example, permits that a single supplier faces a large number of consumers as the sole supplier of a certain good (e.g. a central R&D unit in an enterprise), further environmental conditions, which are assumed to be constant, can promote or hinder the development of market power. Examples for such conditions are different properties of goods, varying resources or production engineering of an enterprise.

In view of the preceding review several functions of markets can be derived: Of all market relationships, price represents the central medium of communication, which combines all relevant information about preferences and actions of market participants in a single metric. Prices and price changes thus afford market participants sufficient guidance for rational decision-making without the need to know all the underlying factors.

The mechanism of pricing contributes significantly to the *reduction of complexity* for all market participants. Ideally, the interplay of market forces also facilitates the distribution to their most efficient uses (*allocation function*) and a balancing of supply and demand.

From the point of view of the individual, markets thus have a *coordinative function*, and from the point of view of the overall system they perform a *market clearing function* (Marshall, 1925). The decentralisation inherent in market systems leads to optimal utilisation of existing knowledge in decision and coordination processes as economic decisions are made by well-informed entities (Hayek, 1945).

Markets furthermore have a *motivational function*. On the one hand economic entities are motivated to enter into exchanges, which improve their provision of resources as profits from transaction may be fully retained. On the other hand, markets provide powerful incentives for enterprises to maximise utilisation of existing technologies, i.e. to perform transformations as efficiently as possible in order to maximise profit by reducing costs. Particularly in dynamic environments, markets trigger effects, which result in an increased readiness to generate innovative solutions to problems (Schumpeter, 1964).

The remarks made above illustrate that markets, in the neoclassical sense, are efficient coordination mechanisms. However, one has to be aware that internal R&D markets are not real markets but rather quasi-markets (Reger, 1999). One major characteristic of internal R&D markets is the relatively small number of market participants. Thus, it is important to establish adequate market structures. In this context auction theory can complement the neoclassical approaches, since it provides some auction forms that can be used for market coordination.

Due to the increasing importance of auctions in recent years (e.g. auction of 3G mobile phone licences), auction theory has become an independent area of research.<sup>16</sup> In contrast to hierarchical fixed-price systems, auction mechanisms contain a price competition between the involved market participants. According to that the price of a transaction is not an exogenously predetermined figure but the endogenous result of the competition between the market participants. On this basis an auction can be defined as a market institution with an explicit system of rules, in which prices and quantities are determined via the individual bids of the market participants (Peters, 2002).

Subsequently, the following fundamental auction forms are introduced:

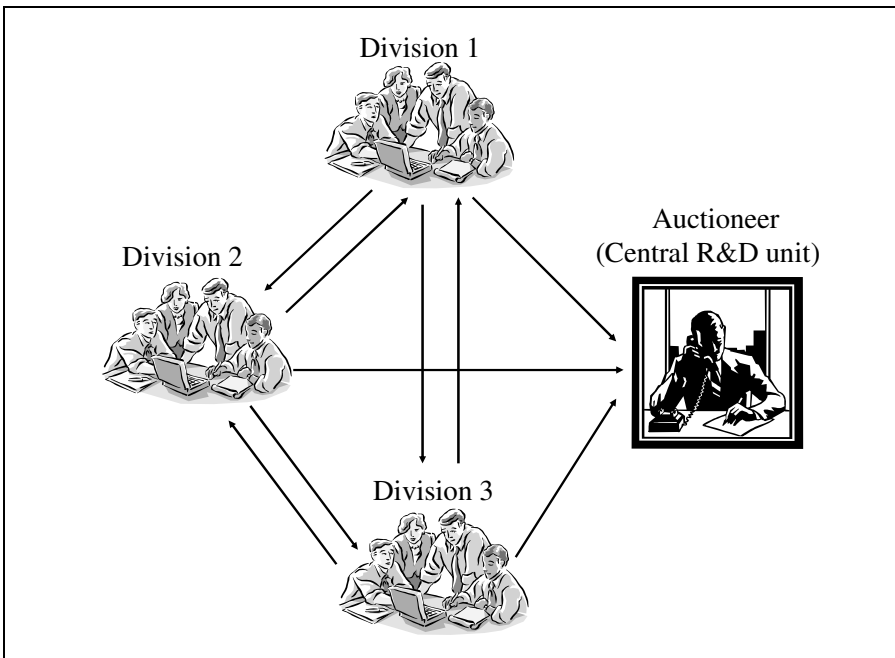
- English auction
- Dutch auction
- First Price Sealed Bid auction
- Vickrey auction

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<sup>16</sup> For an introduction into auction theory refer to Milgrom (1985), Maskin & Riley (1985), McAfee & McMillan (1987), Milgrom (1987), Milgrom (1989), Wilson (1992), Wolfstetter (1996), Milgrom (2000), Brusco & Lopomo (2002), Cramton (2002), Grimm, Riedel & Wolfstetter (2002), Maskin (2004).

The probably most well-known form of auction is the so-called English auction (Amor, 2000; Peters, 2002), in which bidders can make free open bids as long as no other bidder is willing to make a higher bid. In this kind of auction all bidders must be informed about the bids of the other bidders. In this context an auctioneer is responsible for the functioning of the auction. In such a communication system lots of signals are exchanged, which implies that the communication requirements are high. Due to the multitude of signals (each participant always knows the reaction of all co-bidders) the individual bidders do not require any further information. Thus, the information requirements equals zero.

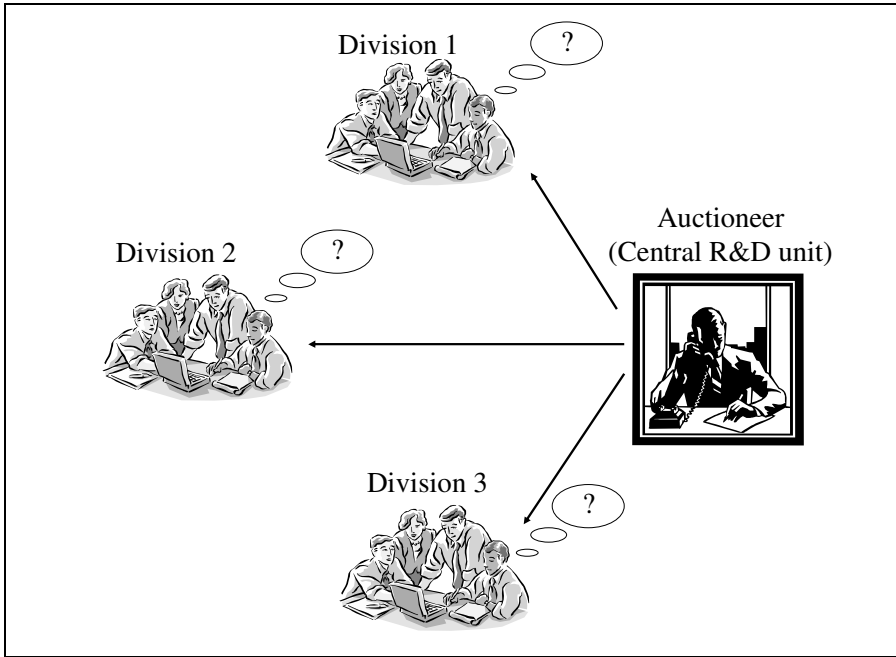
The following example illustrates the situation, when different divisions make their bids for certain R&D projects or services, which they can request from the central R&D unit. The arrows in Figure 10 indicate the communication requirements between the participants of the auction.



**Figure 10: English auction**

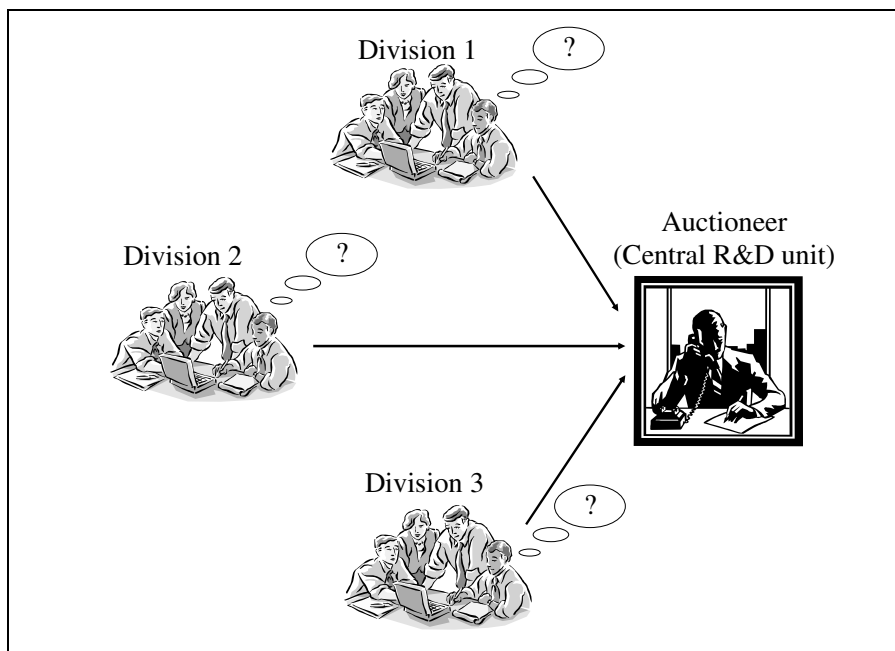
The second fundamental form of auction is the so-called Dutch auction (Amor, 2000; Peters, 2002). This auction form differs quite substantially from the English auction. In a Dutch auction the auctioneer announces prices in falling order for the auctioned good. The good is then awarded to that participant who makes the first bid. Thus, in the example presented above, each division must form a judgement in advance which amount of money it is willing to pay for a certain R&D project or service.

It becomes obvious that the communication requirements in the case of a Dutch auction are substantially lower than they are in an English auction. Rather the behaviour of the individual bidders depends on their assumptions about the behaviour of the co-bidders. Thus, extensive information is required in order to get a clue about the behaviours of all the involved participants. This is also illustrated in Figure 11.



**Figure 11: Dutch auction**

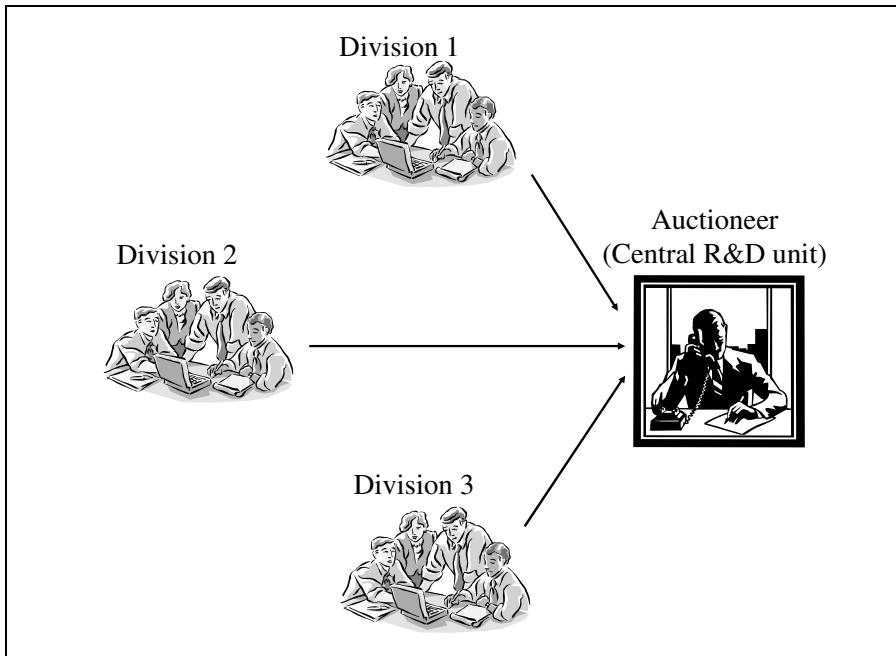
The third fundamental form of auction is called First Price Sealed Bid auction (Amor, 2000; Peters, 2002). In this kind of auction each bidder (e.g. division) makes one sealed bid and the bidder with the highest bid wins the auction. Figure 12 sketches the procedures associated with this form of auction.



**Figure 12: First Price Sealed Bid auction**

The communication requirements in such auctions are very low, since each bidder is only allowed to make one bid. Therefore, there is no need for communication between the involved participants. However, for the same reasons as in Dutch auctions, the First Price Sealed Bid auction implies relatively high information requirements concerning the behaviour of the co-bidders.

The fourth well-known form of auction is the so-called Second Price Sealed Bid auction or Vickrey auction (Amor, 2000; Peters, 2002). Similarly to the First Price Sealed Bid auction the bidders can make one single sealed bid. This indicates that the communication requirements associated with this form of auction are very low. In the example shown below the division with the highest bid awards the auctioned R&D project or service. However, the division does not have to pay the price of its own bid ( $B^*$ ), but the price of the second highest bid ( $B^{**}$ ). In this way the division with the highest bid attains a surplus which results from the difference between its own bid and the second highest bid ( $B^* - B^{**}$ ). This procedure makes clear that there is no need for an individual division to gather information about the behaviour of the co-bidders. Thus, the dominant strategy of each division in a Vickrey auction is to make a single sealed bid which reflects its true estimate of the value of a certain R&D project or service. If this is the dominant strategy and each bidder behaves rationally, then it is apparent that the communication requirements in Vickrey auctions are very low. Moreover, there is no need to collect information about the potential behaviour of co-bidders in such auctions. The general functioning of a Vickrey auction is outlined in Figure 13.



**Figure 13: Vickrey auction**

The different forms of auction described above will also play an important role for the development of a conceptual framework in section 3.2. This framework explains the main elements of internal R&D markets and illustrates that such markets essentially deviate from the central neoclassical assumptions, which were mentioned in section 2.4.2.2. Nevertheless, the neoclassical approaches give some indication of the advantageous of market-driven forms of resource allocation within R&D contexts, as outlined below.

In general, it can be said that the more intense the competition between market participants the better markets can perform the functions discussed above. Total absence of competitive pressure is considered a main cause of market failure (Fritsch, Wein & Ewers, 1996). In the R&D field there often prevail oligopolistic market structures, where a few suppliers and a few requestors are confronted with each other. Moreover, the intensity of competition mainly depends on corporate policies. The different forms of competition in an internal R&D market are discussed in section 3.2.4.

A paper of Vining (2003) provides a framework for understanding within-firm, or internal, inefficiency. It is shown that internal market failures, due to internal negative and positive externalities, internal public good problems, internal information asymmetries, internal monopolies, the presence of uncertainty, create inefficiencies within firms just as they do in normal markets. To sum, there are several causes for market failure such as externalities, 'public goods,' lack of information, 'economies of scale' and intertemporal effects.

**Externalities** are in effect if the activity of an economic entity (household or enterprise) exerts a positive or negative influence on the utility or opportunities of production of another entity without a price being asked in the context of the exchange (Knieps, 2001). Milgrom & Roberts (1992) distinguish between positive and negative external effects. External effects are uncompensated changes in utility which are experienced by individuals and caused by the actions of economic entities. Changes leading to a loss of utility are referred to as negative external effects, and changes leading to an increase in utility are termed positive external effects (Picot, Dietl & Franck, 2002).

Put differently, negative external effects occur if the total social cost is higher than the private cost of the acting entity. A frequently used example for negative external effects are the costs generated by pollution of the environment (e.g. sewage, noise, smoke), which are not necessarily covered by the originator. The diffusion of a technology may serve as example for a positive external effect. This would be the case if a newly developed technology were used by a different enterprise (external) or a different division and/or business unit (internal) and lead to increased effectiveness of the secondary user.

Externalities play a very important role in R&D contexts. On the one hand the results of R&T projects aimed at new businesses and markets can often be used by several divisions and business units (externality of consumption). On the other hand the project results of R&T projects aimed at existing businesses and markets, and particularly the results of new development and enhancement projects are much more specific.

The importance of the specification of property rights should become apparent at this juncture (see section 2.4.3). If property rights are well-defined and the transaction costs of an exchange of rights are negligible, market negotiations lead to efficient equilibria (Coase, 1960). The property rights to the outputs of R&T projects aimed at existing businesses and markets, and particularly of new development and enhancement projects are easily definable. A market-driven allocation of resources thus appears feasible in this context. The property rights to R&T projects aimed at new businesses and markets are much harder to define, due to the extent of externalities. Hierarchic allocation of resources seems more appropriate to such situations.

**'Public goods'** typically preclude the emergence of markets, due to non-rivalry and non-exclusivity. A good is nonrival if the marginal cost of providing it to an additional consumer is zero, whereas it is nonexclusive if people cannot be excluded from consuming it (Pindyck & Rubinfeld, 2001). An often used example for a public good is national defence.

In the R&D context there are also situations where certain project results are nonrival. A basic technology, for example, provides benefits to several divisions and/or business units at zero marginal cost. However, the exclusivity of R&D results can be secured by internal regulations and the allocation of property rights (see section 2.4.3). Furthermore, competitors can be excluded by patents.

The properties of public goods mentioned above are mainly found in R&T projects aimed at new businesses and markets, whose outcome is hard to define and anticipate. The corresponding results can often be used by several divisions and/or business units and the property rights are thus hard to define. In practice this type of projects is normally financed by corporate funds (see section 4.4). R&T projects aimed at existing businesses and markets are, by contrast, clearly defined with respect to the utilisation of outputs and funding as the assigning division and/or business unit typically finances the activities and utilises the results. The same appears to be true for new development and enhancement projects.

It has been mentioned before that **lack of information** can also lead to market failure. This is particularly likely if information about certain properties of products or the quality of products is missing. Consumers are unable to make utility-maximising decisions in the majority of such cases (Pindyck & Rubinfeld, 2001).

The implications for R&D activities are that the lack of information may be particularly high for projects with a long time-to-market, a high degree of innovation and a high degree of uncertainty. Market mechanisms may therefore lead to inefficient allocation of resources for R&T projects aimed at new businesses and markets. However, R&T projects aimed at existing businesses and markets, and particularly new development and enhancement projects are characterised by a comparably higher potential for short-term commercialisation of project results, a higher degree of routine and a higher degree of certainty. Thus, market-driven forms of resource allocation may lead to good results for these types of project.

**Economies of scale** can also lead to market inefficiencies. They are present if a proportional increase in input factors results in a disproportional in all output components. This implies falling unit costs in a one-product scenario (Knieps, 2001).

The phenomenon of scales can also be encountered in R&D settings. R&T projects aimed at new businesses and markets often require substantial specific investments (e.g. into laboratory equipment), which individual business units or divisions are unable or unwilling to make as they cannot assess the utility of the project outputs for their operation. Such investments are therefore often financed by corporate funds. A market-based resource allocation could lead to the suppression of important projects as there might be no demanders (divisions/business units) who are willing or able to pay the price.<sup>17</sup> However, R&T projects aimed at existing businesses and markets, and particularly new development and enhancement projects can normally be implemented with existing infrastructure, which should facilitate the application of market-driven forms of resource allocation.

**Intertemporal effects** also play an important role as explanations of market failure. The notion refers to the time frame from the beginning of a project to the emergence of marketable products and processes.

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<sup>17</sup> For a fundamental discussion refer to Milgrom & Roberts (1992).

This time frame varies from project type to project type. Technologies which are commercially viable only in the long run are often neglected by managements whose success is measured in terms of short-term goals as such R&D objectives exceed personal time horizons (Völker, 2000). Thus, market-driven forms of resource allocation are less suitable for R&T projects aimed at new businesses and markets. Due to the project type-specific characteristics, the incentive problem described above is less pronounced for R&T projects aimed at existing businesses and markets, and particularly for new development and enhancement projects.

In conclusion, neoclassical theory suggests that market-driven allocation of resources is generally possible and may be beneficial for R&T projects aimed at existing businesses and markets, and particularly for new development and enhancement projects. However, the preferred mode of resource allocation for long-term R&T projects aimed at new businesses and markets is hierarchical.

### **2.4.3 Contributions of property rights theory**

#### **2.4.3.1 Foundations of property rights theory**

The centerpiece of property rights theory is the construct of property rights, i.e. the issue how an owner can legitimately dispose his resources.

The following considerations apply in this connexion:

- utility-maximising behaviour of individuals,
- the notion of property rights, i.e. utilisation depends on rights to resources and institutional rules, and
- specification and transfer of property rights causes costs.

Property rights theory is furthermore concerned with the behavioural relationships among economic entities, which arise from the existence of goods and are part of their utilisation.

Property rights can be divided into four aspects (Furubotn & Pejovic, 1972; Alchian & Demsetz, 1973; Picot, 1981; Barzel, 1989):

- the right to use a good (usus),
- the right to alter this good with respect to form and substance (abusus),
- the right to retain profits arising from the use of the good and liability for losses (usus fructus), and
- the right to sell the good and to retain the proceeds.

The theory suggests that the value of a good is not only determined by its physical properties but also significantly by the exercisable rights associated with it. One can speak of a dilution of property rights if the exercisable rights are constrained.

Property rights can be diluted in two ways:

- Firstly, not all rights need to be ascribed to a single entity. For example, a division or business unit has the right to exploit a specific R&D result, but the resulting profits have to be repatriated to the group.
- Secondly, a set of rights can be shared simultaneously by several individuals (Picot, Dietl & Franck, 2002). A public limited company may serve as an example where rights can be diluted by a potentially large number of shareholders, even though there is a high degree of completeness of rights given to each individual.

The transfer of property rights is usually effected by contracts between economic entities or by regulations within enterprises. Participants in transfers of rights interact within institutional frameworks and choose forms of resource utilisation which maximise their respective net utility.

However, this general principle is constrained by the following axioms:

- the more diluted the rights to a resource, the smaller the utility to be gained from disposition, and
- the higher the transaction costs arising from definition, transfer and enforcement of property rights, the smaller the net utility of disposition.

Each participant should incur all positive and negative effects of such transfers in view of allocation efficiency. The dilution of rights and transaction costs nevertheless lead to a suboptimal allocation of factors. The individuals and entities affected are therefore motivated to establish disposal structures and to create institutions, which contribute towards an internalisation of external effects if utility is greater than cost.<sup>18</sup>

#### **2.4.3.2 Assumptions and conditions**

The two fundamental assumptions of property rights theory are the limited rationality of and the individual maximisation of utility by participants. Based on these assumptions three environmental conditions can be identified, which lead to problems of the definition, transfer and enforcement of property rights (Picot, Dietl & Franck, 2002):

- inseparable production processes,
- leverage effects, and

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<sup>18</sup> Proprietors of car parks, for instance, employ wardens to enforce payment by users.

- ownership surrogates.

Contributions of different economic entities to the production of complex goods are often difficult to identify and measure. This generates additional costs for control and measurement, which in turn inflate total transaction cost. This problem is particularly evident in the example of teamwork (Alchian & Demsetz, 1972). The fact that the output of teamwork is not simply the sum of individual contributions by team members (Katzenbach & Smith, 1993) but can only be produced by coordinated interaction gives rise incentives for ‘shirking’ (Milgrom & Roberts, 1992), which must be countered by institutional measures (contracts, organisational arrangements).

Actions of economic entities are often amplified by so-called leverage effects, which can be triggered by modern technology (Barzel, 1989). The development of a new technology which opens up new markets, for example, multiplies the utility, respectively, the income of a company and its stakeholders. It is not possible to ascribe all consequences of individual actions to participants wherever leverage effects significantly amplify the economic consequences of participant action (Picot, Dietl & Franck, 2002). Potential losses of large corporations (external effects) exceed the personal liability of their CEOs by far and can not be internalised due to their magnitude.

All factors that produce incentives similar to ownership are termed property surrogates. They depreciate external effects arising from diluted property rights or losses of welfare. The regulating effect of competition is one of the foremost ownership surrogates (Picot, 1981). This can be illustrated by looking at leaders of large corporations who cannot be easily controlled by shareholders. Competitive pressure in the markets promotes utility-maximising behaviour in leaders and discourages the pursuit of personal goals at the expense of the company’s profit and by implication at the expense of the shareholders. Competition thus dissuades managers from ‘unloading’ negative external effects onto equity holders.

#### **2.4.3.3 *Losses of welfare due to external effects and transaction costs as efficiency criterion***

The assessment of various arrangements regarding property rights (contracts, organisational rules) necessitates a combined efficiency criterion:

- losses of welfare due to external effects, and
- transaction costs

The extent of external effects (see section 2.4.2.4) and the associated losses of welfare are determined by the extent to which actions and their consequences can be attributed to economic entities. This implies that participants will act more efficiently if they hold more property rights to a good. The best choice of alternative property rights arrangements with respect to efficiency is that which guarantees the most complete conveyance of rights to participants.

Unfortunately, because of transaction costs (see section 2.4.4) this idea is of limited practical relevance: The existence of transaction costs dictates that distributions of property rights cannot be evaluated on the basis of losses of welfare through external effects alone. A contract or organisational rule is inefficient if the internalisation of external effects is bought at the price of transaction costs, which exceed the gains of welfare affected by the internalisation.

Thus, the best choice of property rights arrangement is one which minimises the sum of transaction costs and losses of welfare caused by external effects (Picot, Dietl & Franck, 2002).

#### 2.4.3.4 *Critical appraisal*

Property rights theory describes the enterprise as a dynamic web of contractual relations. The theory facilitates the analysis of legislation, rules and contracts between legally independent entities. Property rights theory considers four traditional rights (see section 2.4.3.1). The central prediction of the theory is that participants within a given institutional framework choose forms of resource utilisation and establish rights structures which maximise their respective net utility.

The theory is typically applied to investigations of the relative efficiency of defined distributions of property rights among enterprises and stakeholders (e.g. proprietors, managers, employees, state). It analyses decisions, which lead to a change in the distribution of property rights within enterprises. Property rights theory contributes to the understanding of adequate forms of resource allocation inasmuch as different forms of resource allocation are characterised by different configurations of rights.

Property rights are mainly intangible assets in the context of R&D activity, so-called intellectual property.<sup>19</sup> According to Boer (1999 p.72 f.), “*intellectual property takes many forms. These include identifiable properties, such as trademarks, brand names, patents, and copyrighted works, and far less identifiable property: knowledge about customers, about technology, about how an industry works, about high-quality processes.*”<sup>20</sup> Inventions resulting from R&D activities, for example, are usually protected by filing patents, which secure the exclusive rights of exploitation.

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<sup>19</sup> For an introduction to the theory of intellectual property rights see Maskus (2000).

<sup>20</sup> Boer also notes that “There is also a vast corpus of written information – reports, notebooks, drawings, manuals, memos, computer codes, and so on. Each of these is potentially valuable, as evidenced by the existence of employee confidentiality agreements, noncompete agreements, and bitter legal battles over patent and trademark infringements and the rights for former employees.” (Boer, 1999 p.73).

The acquisition of property and the rights associated with it is crucial to the functioning of internal R&D markets. On the one hand, from a company's point of view, intellectual property is the right to exclude competitors. On the other hand an internal requestor of R&D services (e.g. division) will only be prepared to pay a reasonable price if he acquires the property rights to project output and thus can obtain the resulting profits.

Incentives to engage in R&D activities would be much weaker if there were no institutionalised protection of intellectual property. In the absence of such protection, individual researchers and corporations would have to cover the cost of innovation, but others might be the beneficiaries.

Property rights theory has the following general recommendation concerning organisation: Property rights should be distributed in a manner such that maximally complete bundles of rights are combined with the utilisation of economic resources and assigned to the participant wherever transaction costs permit it.

With regard to the different types of R&D projects, one should note that a certain part of the R&T projects aim at new businesses and markets. The number of potential users of the corresponding project results is therefore high (externalities of consumption). Furthermore, the degree of innovation and consequently the degree of uncertainty are high, which accounts for the fact that project goals are difficult to define precisely at the outset. Moreover, such projects typically have a high time-to-market. Given these conditions, transaction costs for an exact assignment of property rights would be prohibitive.

R&T projects aimed at existing businesses and markets, and particularly development and enhancement projects constitute a different group of cases. Projects of these types can typically be ascribed to a smaller circle of users, i.e. the project results are more specific. As already mentioned, these types of project are comparably characterised by a shorter time-to-market, a higher degree of routine and a higher degree of certainty. The assignment of property rights at acceptable cost thus appears generally feasible, which would enable market-driven allocation from the point of view of property rights theory.

In conclusion, property rights theory suggests that market-driven forms of resource allocation are most beneficial for development and particularly for enhancement projects, followed by R&T projects aimed at existing businesses and markets. The resources for R&T projects aimed at new businesses and markets should rather be allocated via hierarchical, administrative forms of resource allocation.

## 2.4.4 Contributions of transaction cost theory

### 2.4.4.1 Foundations of transaction cost theory

Transaction Cost Theory (Coase, 1937; Williamson, 1975; Picot, 1982) evaluates why certain transactions are carried out more or less efficiently under certain institutional arrangements or, in fact, why they are carried out or not carried out at all. A comparison of costs under different arrangements serves as criterion in the search for the best alternative. Economical use of resources is the main direction of inquiry.

Property rights structures (see section 2.4.3) are considered marginal factors and not discussed extensively under the current approach. Individual transactions are the elementary units of investigation in transaction cost theory. Thus, the manifold relationships of exchange among the highly specialised agents in economic systems based on the division of labour are the point of departure for transaction theorists. The term agent subsumes both individuals and organised entities such as enterprises and the state. Rather than on actual exchange of goods between agents, the theory concentrates on logically separable transfers of property rights. These transfers are termed transactions (see section 3.2.4). Costs incurred by participants of transactions are referred to as transaction costs and serve as efficiency criterion. Milgrom & Roberts (1992) subdivide transaction costs into coordination and motivation costs.

“Coordination costs arise from the need to determine prices and other details of the transaction, to make the existence and location of potential buyers and sellers known to one another, and to bring the buyers and sellers together to transact.” (Milgrom & Roberts, 1992 p.29).

“The transaction costs associated with the motivation problem are primarily of two kinds. The first type of costs are those associated with informational incompleteness and asymmetries – situations in which the parties to a potential or actual transaction do not have all the relevant information needed to determine whether the terms of an agreement are mutually acceptable and whether these terms are actually being met. [...] The second type of transaction costs connected to the motivation problem arise from imperfect commitment – the inability of parties to bind themselves to follow through on threats and promises that they would like to make but which, having made, they would later like to renounce.” (Milgrom & Roberts, 1992 p.29 f.).

According to Picot, Dietl & Franck (2002) transaction costs can also be classified into:

- *ex ante* transaction costs, i.e. costs of services which lead to a contract (information, negotiation and legal costs), and
- *ex post* transaction costs, that is, costs incurred for the enforcement of agreements (monitoring, conflict management, renegotiation costs).

Economic entities are subject to:

- limited rationality (due to incomplete information),
- opportunism (personal interest, double-dealing), and
- risk neutrality.

The governing maxim could thus be worded: ‘Organise your transactions as to minimise your cost from incomplete knowledge, and at the same time try to protect yourself against opportunistic behaviour.’

#### 2.4.4.2 *Assumptions and conditions*

Transaction cost theory essentially considers three classes of conditions (Picot, Dietl & Franck, 2002):

- behavioural assumptions,
- environmental factors, and
- transaction atmosphere.

Two **behavioural assumptions** are considered fundamental to transaction cost theory. The first is derived from behaviourist decision theory (see section 2.4.1) and postulates bounded rationality. Participants in transactions intend to act rationally. However, individuals’ limited cognitive capacity for information processing constrains the desired rationality. The second behavioural assumption concerns opportunistic behaviour. It is surmised that participants in transactions pursue their respective self-interest in transactions by lying, fraud, withholding information etc.

Among the central **environmental conditions** (properties of transactions) are:

- uncertainty,
- asset specificity, and
- frequency.

Williamson (1985) differentiates two kinds of uncertainty in the context of transactions:

- parametric uncertainty, i.e. uncertainty of the situational conditions of the transaction and their future development, and
- uncertainty of behaviour, which is largely attributed to the possibility of opportunistic behaviour.

In this context it should be noted that *ex ante* and *ex post* costs increase with the degree of uncertainty pertaining to a transaction. *Ex ante* information, negotiation and contract costs increase as uncertainty forces transaction partners to make arrangements for several contingencies. *Ex post* transaction costs rise with uncertainty as even the most thorough (and expensive) *ex ante* arrangement cannot cover all possible contingencies, i.e. contracts in situations of uncertainty are often incomplete. However, one has to consider that the degree of uncertainty does not affect production costs.

As regards specificity, companies can utilise more or less specialised resources. Specialised resources, which are designed for the production of specific goods and services, may lead to savings in production costs compared to more general resources, which can be employed in the manufacture of different goods. Transaction-specific investments thus reduce production costs via the specialisation advantage, but they can also inflate transaction costs. The opportunity costs of contract cancellations rise as specialised resources lose value if they are redeployed to alternative uses. Moreover, the agreement and application of rules limiting or inhibiting opportunistic behaviour also cause transaction costs. Generally speaking, the costs of transaction-specific investments are not fully predictable. There is a trend for transaction costs to increase with each transaction, while production costs decrease.

Frequent identical transactions can create scale effects (Milgrom & Roberts, 1992; Boer, 1999), i.e. transaction costs and production costs decrease as the frequency of transactions increases. The advantages of arrangements tailored to specific transactions can thus be utilised at lower cost. The implications of scale effects within the scope of a market-driven allocation of scarce R&D resources were discussed in section 2.4.2.4.

The third condition identified at the beginning of the present section is **transaction atmosphere**, which subsumes all socio-cultural and technical factors, which affect the transaction costs of various instruments of motivation and coordination in a given situation. The aforementioned model of behavioural and environmental assumptions is too weak to explain interactions between factors, which economic agents consider to have “*a value of their own*” (Williamson, 1975 p.37).

Friendly participants may conduct very specific transactions without expensive safeguards against opportunistic behaviour because fair interaction as such represents a value for them. Beliefs shared by friends, communication and friendship itself are 'goods,' which would be at risk if one of the partners behaved opportunistically and thus make external institutions unnecessary. Norms and values accepted and understood by the participants have similar effects in that they socially constrain opportunistic behaviour and facilitate information and communication processes accompanying the exchange. It would therefore seem logical that diverse socio-cultural groups may successfully use different institutions as instruments of coordination and motivation in situations comparable with respect to specificity and uncertainty. The so-called clan organisations described by Ouchi (1980) rely heavily on atmospheric factors such as norms, values and beliefs.

It has to be mentioned at this juncture that the available technical infrastructure and especially information technology are also significant determinants of the transaction costs of different communication and motivation structures (Picot & Franck, 1992). Information and communication technology (ICT) supplement human limitations with respect to information processing and communication and aid the initiation, completion, execution, control and adjustment of exchange agreements. Furthermore, technology facilitates the handling of uncertain and specific transactions by way of improved flexibility, transparency, control and documentation. This enables new forms of organisation (Picot, Reichwald & Wiggand, 2001).

#### **2.4.4.3 Transaction costs as efficiency criterion**

Transaction cost theory views the production costs and transaction costs incurred by the participants of an exchange as measure of efficiency. According to Picot, transaction costs include all sacrifices and disadvantages, which have to be accepted by the participants in order to bring about the exchange of services (Picot, 1991; Picot, Dietl & Franck, 2002):

- initiation (travel, communication and consulting costs as well as certain overheads of purchasing, sales, development and production engineering),
- agreement (negotiation costs and costs of legal advice and of coordination and planning of sales, development, purchasing and production),
- execution (e.g. cost of control of exchange process, management cost of leadership and coordination),
- monitoring (of quality, deadlines, purchasing),
- adjustment (additional costs due to post hoc changes in quality, quantity, prices, deadlines).

It must be emphasised at this juncture that assessments should include intangible or 'soft' expenditures, such as effort and time along with 'hard' fiscal measures (Picot & Dietl, 1990).

One of several alternative forms of organisation (e.g. market vs. hierarchy) is considered more efficient if transaction costs are lower. However, it is often difficult to quantify the exact costs of manufacturing a good or to attribute cost components to specific causes. It is even more difficult to pinpoint transaction costs arising from the initiation and execution of an exchange, or to attribute general costs of control to individual transactions.

Fortunately, it is not necessary to measure exact production and transaction costs. The issue of interest is not the precise cost but the question, which of several possible arrangements for a given transaction creates the lowest cost in relative terms. Often, broad indicators and knowledge of trends provide sufficient information to determine the most efficient arrangement.

#### **2.4.4.4 Critical appraisal**

The optimisation of the exchange of services between specialised agents is at the core of transaction cost theory. The forms of resource allocation encountered in R&D contexts are often highly complex. A simple transaction cost specific notion of institutional arrangements is thus unsatisfactory with regard to an examination of alternative forms of resource allocation in this area. A differentiation and isolation of alternative forms of resource allocation based on transaction costs appears problematic because as the distinctions between forms of resource allocation themselves are often blurred. The discounting of other relevant factors is just another obstacle to the practical application of transaction cost theory.

Besides efficiency, distribution of power among transaction participants and their desire to extend power should be taken into account in choosing an adequate form of allocation. Even less efficient forms of organisation can prevail due to specific constellations of interests and power.

Transaction cost theory moreover discounts the fact that different forms of resource allocation create varying utility. Particularly R&D functions require careful examination of the potential utility of alternative organisational structures rather than a narrow focus on known costs of alternative forms of organisation. For example, the utility of an alternative R&D organisation can depend on potential revenue from innovation by spillovers into other product areas or on learning effects, which may arise from the internalisation of R&D (Specht & Beckmann, 1996).

Moreover, the fact that a clear separation of production and transaction costs is virtually impossible limits the application of transaction cost theory even further (Milgrom & Roberts, 1992).

Despite its limitations, transaction cost theory makes some important contributions with respect to the objective of the present investigation. The approach explains why institutions exist and why it can be advantageous to use different institutional arrangements (market vs. hierarchy) to conduct and organise specific transactions. The theory also permits a comparison of alternative forms of organi-

sation of economic exchanges with respect to their efficiency. Moreover, transaction cost theory can integrate and analyse results of other theories of organisation (e.g. the issues of incentives and opportunistic behaviour, which are highly relevant to R&D activities). Furthermore, the theory raises another important issue in that it argues that precise fiscal valuations of transactions are not always possible and indeed not necessary if trends are known. Cost drivers and their orders of magnitude need to be estimated in order to pinpoint trends and tendencies.

The underlying point of view concerning recommendations for institutional arrangements will be based on the assumption that it is not possible and realistic to base decisions about forms of resource allocation on detailed quantitative cost metrics alone. Additionally, it is necessary to investigate essential patterns of economic causation and to estimate trends concerning the utility of alternative forms of resource allocation.

The classification of transaction costs into coordination and motivation costs (Milgrom & Roberts, 1992) calls for a differential analysis with respect to the choice of the adequate form of allocation. Based on the features of the types of R&D projects, it can be stated the following from a transaction theoretical perspective:

Due to their project type-specific characteristics long-term R&T projects aimed at new businesses and markets are characterised by relatively high motivation and coordination costs. One of the reasons for this is that the demand side is judged by its short and medium-term results. Motivation and incentive costs of R&T projects aimed at existing businesses and markets, and particularly of new development and enhancement projects are, by contrast, lower as positive economic results can be expected in the short run.

Moreover, the application of modern ICT results in a reduction of transaction costs regardless of the project type. This may lead to a substitution of previously hierarchical transactions by market transactions (Benzoni & Grzegorzewski, 2001).<sup>21</sup> Following Benzoni & Grzegorzewski (2001) the remainder of the present section aims to explain this phenomenon.

It is assumed that the extremes market and hierarchy represent the only alternative forms of resource allocation. It is furthermore assumed that transaction costs ( $TC$ ) are composed of a fixed part ( $TC_f$ ) and a variable part ( $TC_v$ ), which implies that  $TC = TC_f + TC_v$ .

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<sup>21</sup> Malone, Yates & Benjamin (1987) note an “overall shift from hierarchies to markets.” Sandbill (1998) proposes that the use of information and communication technology leads to a general reduction of costs, and that communication-intensive mechanisms of coordination are thus increasingly attractive.

It is also supposed that variable transaction costs are positively correlated with the degree of specificity. Based on these assumptions, there are three possible reasons for the effect of sinking transaction costs:

- sinking fixed costs,
- sinking variable cost, and
- sinking specificity of transactions.

It is also the case that markets have lower fixed transaction costs than hierarchies, and the elasticity of transaction costs to specificity is higher than in hierarchies.

#### Case 1: Sinking fixed costs

In the context of modern ICT, sinking fixed costs can be interpreted as better cost-benefit ratio of hard- and software. Both market and hierarchy-driven allocation benefit from lower fixed costs. Because the elasticities of specificity remain unchanged, the degree of specificity at which  $TC_{market} = TC_{hierarchy}$  is true also remains the same. Therefore, a change in fixed transaction costs does not give rise to a substitution of hierarchical by market-driven forms of resource allocation.

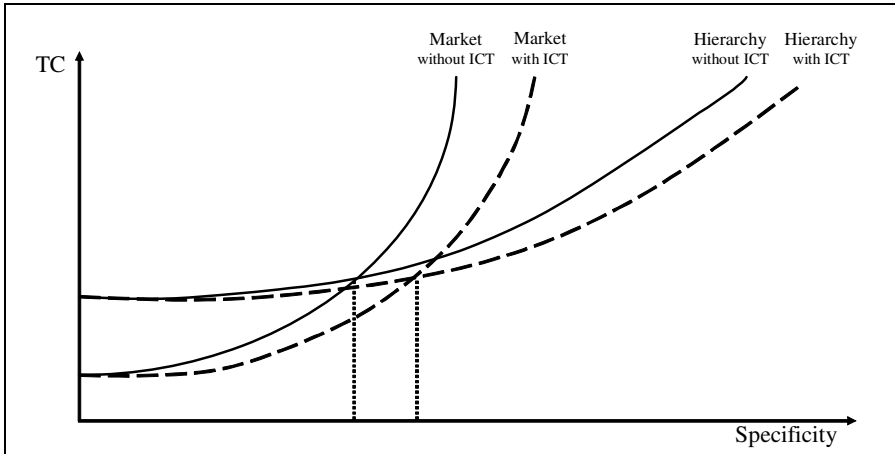
#### Case 2: Sinking variable costs

The use of modern ICT does not only lead to a reduction of fixed transaction costs but also to a reduction of variable transaction costs. The costs arising if an additional unit 'specificity' needs to be dealt with are considered variable. The following simplifying assumptions are made: A coordination unit  $x$  is defined (e.g. the number of bytes transmitted in the process), and a price  $px$  for the transmission of one unit over a given distance  $d$  is assigned. On this basis the following equation for determining total transaction costs can be derived:  $TC = TC_f + F(x, px, d)$ .

Technological advances lead to reductions in price ( $px$ ). It can be assumed that that the degree of specificity is positively correlated with the quantity of coordination units ( $x$ ), which causes a stronger decrease of costs for specific transactions than for unspecific transactions. Similarly, transactions over greater distances ( $d$ ) lead to greater cost reductions than transactions over shorter distances. Thus, it can be stated that transaction costs undergo a shift which causes previously hierarchical transactions to be coordinated by market mechanisms.

The implication for R&D activities is that modern ICT (e.g. Intranet) become the enabler of market-driven resource allocation and lead to improved efficiency from the perspective of transaction cost theory.

Figure 14, below, illustrates the substitution of hierarchical by market-driven forms of resource allocation.



**Figure 14: Change of transaction cost relations by means of information and communication technology<sup>22</sup>**

### Case 3: Sinking specificity of transactions

If one supposes that the degree of specificity is not externally defined but can be reduced by advances in ICT, technology influences which transactions can be carried at the lowest cost through either market or hierarchical mechanisms. With the help of technology, information and know-how can be more easily obtained from third parties. This helps to build symmetry of information between the partners, which in turn reduces the risk of opportunistic behaviour.

An adequate supply of information is vitally important for the success of R&D activities. It becomes more and more evident that the factor information is evolving into a good, which is independent of the production process and traded in separate markets. At the same time, the half-life of knowledge is decreasing dramatically, which can also be explained by the fact that information technology facilitates the ever faster dissemination of information throughout the enterprise. Moreover, specific implicit knowledge, also known as ‘tacit knowledge,’ (Miller & Morris, 1999) can be transformed into explicit and generally available knowledge much more quickly thanks to information technology. Thus, a high time-specificity for the factor knowledge can be assumed. However, a lower degree of specificity caused by technological advances does not necessarily entail a shift from hierarchy to market (Benzoni & Grzegorzewski, 2001).

<sup>22</sup> Following Benzoni & Grzegorzewski (2001).

In conclusion, transaction cost theory suggests that market-driven allocation of resources is generally possible and may be beneficial for R&T projects aimed at existing businesses and markets, and particularly for new development and enhancement projects. However, hierarchical, administrative forms of resource allocation should be preferred for long-term R&T projects aimed at new businesses and markets. Moreover, it was shown that the use of modern ICT can lead to a substitution of hierarchical by market-driven forms of resource allocation.

### **2.4.5 Contributions of principal agent theory**

#### ***2.4.5.1 Foundations of principal agent theory***

Principal agent theory is closely related to transaction cost theory inasmuch as it centers on the institution of contract and its role in relationships of exchange between a principal and an agent. (For a fundamental discussion refer to Jensen & Meckling, 1976; Pratt & Zeckhauser, 1985; Spremann, 1990).

Principal agent theory is based on four fundamental principles:

- the objectives of an agent are aligned with the objectives of a principal by way of incentives,
- directive control of behaviour through creation of norms and sanctions of deviations,
- improvement of the information system, and
- market mechanisms for the control of an enterprise.

A principal must control the agent in order to achieve compliance with his goals, which creates costs of control.

The two fundamental problems principal agent theory attempts to solve are:

- the asymmetry of information between principal and agent (hidden information), and
- hidden action, i.e. a principal does not know the behaviour of an agent.

The relationships between proprietors and CEOs, between CEOs and boards of directors, and between leaders and their subordinates are typical examples of such relationships within enterprises. In these cases agents delegate tasks and decision-making rights to partners who obtain a (financial) reward for their activity. Such transfers allow principals to utilise specialisation and information advantages of agents, but they also cause problems: The risk that an agent may act against the interest of a principal increases with the lack of knowledge of the agent's motives and actual performance behaviour.

Principal agent theory views organisations and the relationships with the environment as a network of explicit and implicit contracts (Jensen & Meckling, 1976).<sup>23</sup> These contracts define rights, responsibilities and obligations of the partners of exchanges and regulate the distribution of revenues.

#### **2.4.5.2 Assumptions and conditions**

As most frameworks, principal agent theory makes certain environmental and behavioural assumptions. Maximisation of individual utility, uneven distribution of information and the readiness of agents to take risks are the objectives of investigation.

The assumed disposition of principals and agents to maximise their respective utility is characterised by the following features (Ebers & Gotsch, 1993):

- Behaviour is guided by given and stable preferences.
- It is geared towards individual utility.
- Opportunistic practices such as fraud and deception, the withholding of services, misrepresentation of services and selfish interpretation of contracts are part of the behavioural repertoire.
- The utility function encompasses a broad spectrum of monetary goals (e.g. salaries, bonuses, dividends) and non-monetary goals such as career advancement, prestige, power, spare time and self-actualisation.
- The participants behave rationally and expect rational behaviour of their partners, which implies that their behaviour is generally predictable and can be controlled in advance by contractual agreement.
- The partners may have different dispositions towards risk-taking. Risk neutrality of principals and a tendency of risk avoidance in agents are often assumed.

Principal agent theory distinguishes three information problems, which are characterised by different underlying problems of coordination and motivation (Milgrom & Roberts, 1992; Picot, Diel & Franck, 2002):

- adverse selection,
- moral hazard, and
- hold up.

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<sup>23</sup> They describe organisations as “a nexus of contracts between individuals”.

**Adverse selection** means that the principal has no knowledge of certain unchangeable properties of the agent himself or of the services offered by the agent prior to the contract. Agents may conceal bad or below-average performance, or well-performing agents may withdraw from the market, which can lead to the selection of undesirable partners (e.g. recruitment of employees). Asymmetries of selection prior to contract or service are also known as ‘hidden information’.

‘Hidden action’ represents a different problem where there is an asymmetry of information between the beginning and the conclusion of the contractual relationship. The principal has insufficient knowledge of the action scope of the agent and his true performance. Due to his individual leeway an agent may choose to perform services in such a way that his actions cannot be observed by the principal without cost. The term ‘**moral hazard**’ refers to opportunistic exploitation of the principal’s information disadvantage (e.g. the board of directors can hardly evaluate the real performance of a CEO).

‘**Hold up**’ denotes asymmetries of information between the parties of a contract (principal and agent) and third parties (e.g. courts of law do not have perfect information and therefore cannot definitely judge if the parties to an agreement have fulfilled a contract or not). The parties of a contract are able to identify their respective opportunism, but they cannot prevent it as they depend on each other because of specific investments.

#### 2.4.5.3 *Agency costs as efficiency criterion*

Future environmental situations and actions of individuals would be fully predictable in a world of cost-free and complete information. Hence, there would be no problems of motivation and coordination. The structures of division of labour/specialisation emerging under such conditions maximise wealth and are referred to as first-best solutions (Picot, Dietl & Franck, 2002). Due to incomplete and unevenly distributed information, there are deviations from first-best solutions in reality, which are called second-best solutions.

Agency cost is the difference between second-best and first-best solutions and comprises the following components (Jensen & Meckling, 1976):

- Costs of the measures of the principal, which are aimed at improvements to agent service (e.g. costs of contracts, costs of sharing profits, costs of controlling and monitoring activities. These costs can be called costs of monitoring and control).
- Costs incurred by the agent in fulfilment of his contractual obligations to the principal (e.g. costs of reporting, costs of information about the expectations of the principal or costs arising from liability for damages).
- Costs of the loss of utility caused by agent services, which fall short of the possible maximum of utility for the principal.

There are several approaches to the assessment of incentive systems and recommendations for various agency relationships.<sup>24</sup> It should be noted here that modern information and communication systems improve the effectiveness of incentive systems as they promote the measurability and attribution of decentral decision results. Highly aggregated measures of results can be broken down and attributed to smaller organisational units at acceptable cost. This entails that the performance of small units down to the performance of the individual contributor becomes measurable and can serve as a basis for performance-related incentive systems (Sandbillier, 1998).

#### 2.4.5.4 *Critical appraisal*

Principal agent theory describes organisations as networks of contractual relationships. The quality of services depends on the efficient contractual regulation of relationships between principals and agents. The latter are economic exchanges based on agreements between incompletely informed participants who strive to maximise their own utility and have contradictory goals. A central shortcoming of the theory is its narrow focus on individual contracts and its negligence of the role of 'regulatory third parties,' such as laws, patents and labour relations. The *ex ante* perspective of the theory moreover ignores all difficulties which may develop as contracts are fulfilled. Such difficulties are particularly likely to arise in the highly complex area of R&D.

An assessment of different forms of resource allocation with varying degrees of asymmetry of information and opportunistic behaviour must take into account compatible incentive systems. Compatibility of incentives is given if the incentive premium function is designed such that the agent can only improve his expected utility if the expected utility of the principal rises after subtraction of the premium (Laux & Liermann, 1997). The usefulness of principal agent theory for the design of optimal incentive systems is limited as it relies on knowledge of utility functions. The theory can nevertheless be applied to a range of problems related to the delegation of decisions. Steering committees, for example, are both principals with respect to the selection of projects and delegation of tasks, and agents who should act in the interest of management and proprietor(s). It is worth investigating how an incentive system should be designed to support the paramount objective of value creation (see section 7.3). Principal-agent relationships in R&D contexts are often made up of multiple interactions, which create opportunities for learning and better sanctioning of opportunistic behaviour.<sup>25</sup>

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<sup>24</sup> For a fundamental discussion of principal-agent problems in the R&D context refer to Holmstrom (1989) and Rotemberg & Saloner (1993).

<sup>25</sup> For a fundamental discussion refer to Axelrod (1984).

The following suggestions can be derived from principal agent theory in the context of the present investigation: Asymmetries of information between agents and principals are particularly large, due to the high degree of innovation, the high degree of uncertainty and the long time-to-market involved in R&T projects aimed at new businesses and markets. This tends to inhibit a market-driven regulation of contractual relationships. R&T projects aimed at existing businesses and markets, and particularly new development and enhancement projects involve a greater proportion of explicit knowledge, because they are characterised by relatively higher degrees of routine and certainty and a higher potential for short-term commercialisation. These characteristics in turn facilitate the use of market mechanisms and the making of contracts.

In conclusion, principal agent theory suggests that market-driven forms of resource allocation are most suitable for development and particularly for enhancement projects, followed by R&T projects aimed at existing businesses and markets. The resources for R&T projects aimed at new businesses and markets should rather be allocated via hierarchical, administrative forms of resource allocation.

## **2.4.6 Contributions of the value management approach**

### **2.4.6.1 Foundations of the theory**

Proponents of the notion of shareholder value (Rappaport, 1986; Copeland, Koller & Murrin, 1990) argue that an enterprise should increase the wealth of its shareholders by maximising its own market value. The theoretical foundations of the model have been known since the inception of the theory of capital markets. However, Rappaport's (1986) ground-breaking work and subsequent research by Copeland, Koller & Murrin (1990) only recently opened up new avenues of broad application. The basis of the value management is the notion of discounted free cash flow (DFCF). The value of an enterprise corresponds to the flow of all liquid assets, which can be obtained from business activity. Shareholder value is obtained by subtracting liabilities from this figure.

A shareholder value orientation suggests that it is efficient to link management compensation to the market value of an enterprise. The transfer of rights to retain profits to managers internalises positive external effects such as increases in market value (Picot, Dietl & Franck, 2002). Value management can contribute to the solution of the principal-agent problem by the same token. Compensation linked to market value aligns the interests of agents and principals.

#### 2.4.6.2 *Assumptions and conditions*

The so-called Fisher separation (Fisher, 1906) holds that irrespective of individual consumption preferences of economic entities decisions are favoured, which maximise the market value of all flows of income of an enterprise. Under the assumption of compatible incentives these decisions will also maximise shareholder value. A generally accepted decision rule, which favours investments with positive capital value, is derived from the Fisher separation. However, practical application of the value approach assumes functioning capital markets. The market value of an enterprise is then equal to all future net revenues from business activity.

In order to determine the net present value of an enterprise (or a project) a time frame needs to be defined for which future cash flows should be estimated. It should be noted, though, that the uncertainty of the cash flow prognosis increases with time span. The results of business activity after the defined time span are estimated as residual value, which is usually inversely related to the length of the time frame. It accounts for a large portion of the value of an enterprise. There are different ways of determining residual value. One can firstly employ the formula of perpetuity, which assumes that after the time span has elapsed only investments are possible, which have an internal yield equal to capital cost. It is thus assumed that management is not able to create additional value. Depending on market and competition, one could secondly assume a steady percentage growth of the free cash flows corresponding to the last period of the time frame (Copeland, Koller & Murrin, 1990).

The basis for the calculation of the free cash flow is operating profit, i.e. earnings before interest and tax. Subtraction of tax, addition of depreciation and consideration of long-term reserves leads to gross cash flow. Free cash flow is determined by subtracting investments into capital assets and considering changes in working capital. Free cash flow is excess liquidity available for payment of capital interest, dividends and for servicing liabilities. The value of an enterprise is determined by discounting annual free cash flows with weighted average cost of capital, which are derived from the opportunity costs of capital givers (loan capital and equity) and the capital structure of the enterprise.

The total capital cost of the enterprise thus consists of the costs of equity and loan capital. The cost of loan capital (capital for which interest must be paid) can be calculated under two different assumptions. The calculation can firstly be based on an average cost rate derived from historical data assuming that these rates will also apply in the future. A second method is to take into account future developments of interest rates for loans in the capital market or changing risk ratings by merchant banks.

The capital asset pricing model (CAPM) is used to determine capital cost, which is adequate to risk (Milgrom & Roberts, 1992). The cost of equity capital<sup>26</sup> consists of the so-called 'risk-free' nominal rate of interest<sup>27</sup> and a risk surcharge, which can be derived from the market rate of interest and the enterprise-specific risk factor Beta. CAPM thus supposes a positive linear relationship between the cost of equity capital and the factor Beta if the latter is positive.<sup>28</sup>

### 2.4.6.3 *Expected future cash flows as efficiency criterion*

There are several instruments for the value-oriented control of enterprises. Among most popular methods are (Boer, 1999; Lammerskitten, Langenbach & Wertz, 1997): Rappaport's discounted free cash flow, Steward's economic value-added and Lewis' cash flow return on investment. The theoretically most appealing approach is the DFCF (Hoffmann & Wüst, 1998), which relies on future expected cash flow in order to determine the value of an enterprise. Free cash flow is a particularly suitable metric inasmuch as it is relatively insensitive to balance window dressing. It thus facilitates a plausible and reliable control of an enterprise (Breid, 1994). Free cash flows must be discounted for the present in order to be evaluated and compared. The interest rate for discounting should be equivalent to minimum yield expected by lenders and equity holders. This procedure outputs the discounted free cash flow or net present value of future free cash flows (Pape, 1999).

It can be argued that all R&D projects with a positive capital value contribute to the total value of an enterprise (Fisher, 1906; Völker, 2000). However, given scarce resources allocation decisions should be made in favour of projects with the highest relative value-added. It has to be noted at this juncture that the present study investigates not only criteria for the selection of individual projects but also the general efficiency of alternative forms of resource allocation.

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<sup>26</sup> Cost of equity capital = 'risk-free' nominal rate of interest ( $i$ ) +  $\beta$  \* [market rate of interest ( $m$ ) - 'risk-free' interest ( $i$ )]

<sup>27</sup> Mean interest rate of a 'risk-free' loan (government bond) with a run equivalent to the time horizon of the cash flow prognosis.

<sup>28</sup> The literature suggests three analogous methods for the determination of the Beta factors of non-public enterprises: (1) analogy with a single public limited company (pure-play technique), (2) average value of the whole industry (industry Beta), and (3) average value of a selected reference group of public limited companies (peer group). Cf. Lammerskitten, Langenbach & Wertz (1997).

#### 2.4.6.4 *Measures of value-added as efficiency criterion of alternative forms of resource allocation*

Comparisons of alternative forms of allocation like market and hierarchy require metrics. Efficiency and effectiveness are the foremost metrics used for such comparisons.

Effectiveness indicates to what extent specific forms of resource allocation facilitate the selection and completion of the 'right' R&D projects. A variety of qualitative and quantitative criteria can be used to answer this question. They include the assessment of strategic potential (access to future markets, new technologies, new areas of business),<sup>29</sup> the achievement of technical goals (improvement of methodological competencies), the increase of the value of the enterprise (indicated by share prices), the contribution of the project to net present value (NPV) and the rate of innovation (share of new products of the total turnover) (Boer, 1999).

Efficiency measures proper allocation of resources. The quantitative and qualitative metrics of efficiency used in the assessment of R&D activities include improved adaptability of the enterprise to environmental changes, flexible control of resources, precise estimation of expected costs, acceleration of the allocation process, reduction of allocation costs etc.

In addition to efficiency and effectiveness, secondary effects should be considered in decision making. Secondary effects can be desirable or undesirable consequences of actions. The transformation from hierarchical to market-driven forms of resource allocation may for example lead to higher transparency and stronger interaction between requesting divisions and/or business units on the one hand and supplying R&D units on the other hand. This implies that additional ideas can be generated or that synergies can be identified early on and utilised accordingly. However, higher transparency also increases the risk of loss of knowledge and exposure to competitive intelligence (Baratte & Kirsten, 2003). Many enterprises attempt to counter this threat by introducing sophisticated systems of knowledge management (Rappaport, 1986).

In summary it may be said that the comparability of the three effects described above is problematic.

Measures of value-added such as DFCF permit, in principle, to capture effectiveness, efficiency and secondary effects in one aggregated measure. This suggests that alternative forms of resource allocation should be assessed on the basis of value-based measures. However, the fiscal NPV and DFCF procedures are too

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<sup>29</sup> "The great challenge in innovation is linking emerging technologies with emerging markets. If it were just a matter of linking emerging technologies with existing markets (or vice versa), the coupling would be relatively easy. But when both are emerging, it is a delicate, coevolutionary process: as technologies emerge, they affect the markets, and as markets emerge, they influence the technologies." (Brown, 1997 p.xiii).

limited in scope for this purpose. Supplementary methods have been proposed by several practitioners.

Rappaport's notion of 'value drivers,' for instance, demonstrates that DFCF can be reduced to indicators like operating profit margin, investments into plants and current assets, growth of turnover, duration of growth, capital cost and tax rate. This reduction permits quantitative measurement and qualitative assessment of the components.

The 'Valcor-Matrix' (Gomez & Weber, 1989) is exemplary of instruments based on value drivers. It connects utility potentials (e.g. organisational structures) to value drivers. The assignment of specific aspects to value drivers does not claim exclusiveness, but it illuminates where the largest leverage effects are to be expected (Gomez, 1993). An analysis by means of the matrix serves as a heuristic for the identification of the main effects and for the question where and how certain activities lead to value creation. Such a heuristic is particularly useful for the evaluation of the potential value creation of alternative forms of organisation.

The aim of the present investigation with respect to alternative forms of resource allocation in R&D is therefore to study their respective contributions to value creation in an enterprise.

#### **2.4.6.5 Critical appraisal**

The concept of value management serves as a guide for a multitude of decisions and as an indicator of success. It aids operationalisation in the evaluation of alternative forms of resource allocation and project selection.

However, three significant problems emerge with respect to operational application (Lammerskitten, Langenbach & Wertz, 1997):

- the problem of prognosis,
- the problem of compounding, and
- the problem of manipulation.

The problem of prognosis relates to the difficulty of assessing future free cash flows adequately. The problem of compounding reflects the fact that there are various horizontal and vertical compounds within multidivisional enterprises, which render the assignment of cash flows and/or capital costs difficult or even impossible. Technological conditions lead to high degrees of vertical compounding in some industries (e.g. chemicals). Joint sales channels and shared services such as treasury or human resources may also give rise to assignment problems. Moreover, principal-agent relationships are at the core of manipulation problems. It was proposed in section 2.4.5 that principals and agents have conflicting goals, and that there are a range of incentive systems, which ameliorate such conflicts (Kah, 1994). The approach of shareholder value suggests that systems should be preferred which can be defined in terms of capital theory (Lammerskitten, Lan-

genbach & Wertz, 1997; Boer, 1999). Especially DFCF or DeltaDFCF appear to be accompanied by considerable manipulation problems. The use of DFCF entails the problem of hidden information, i.e. the principal does not know whether quantities which are better assessed by agents are in fact realistic. DeltaDFCF suffers from an added effect of hidden action. Within a planning period an agent can influence the FCF in his favour by taking non-strategic and short-term action (Rappaport, 1995).

Such problems of operationalisation are particularly relevant to R&D activity. The contribution of a project team to the future value of a project is hard to gauge if others have responsibility for downstream tasks (e.g. production, launch). It is nevertheless important and necessary to build rules for incentive systems, which support value-oriented allocation of R&D resources.

In conclusion, it can be stated that every R&D project with a positive net present value contributes positively to the value of the enterprise. Due to the project type-specific characteristics the net present value method is suitable for the assessment of R&T projects aimed at existing businesses and markets and particularly for the assessment of new development and enhancement projects. In the present context it is argued that the notion of value management also enables the comparisons of alternative forms of resource allocation. Thus, a value-based approach will be employed for subsequent comparisons of alternative forms of resource allocation, such as hierarchy and market.

## 2.5 Conclusions

At the outset of this chapter fundamental terms and relationships were explained that are crucial for the general understanding of the present investigation. Thereafter, section 2.2 dealt with the state of the art of R&D resource allocation. Moreover, section 2.3 gave an overview of the relevant literature concerning the internal market concept, which has been identified as the major new trend in the field of R&D resource allocation. In section 2.4, additionally, theoretical concepts that are relevant to the investigation were introduced and scrutinised.

In general, it was illustrated that the effective and efficient allocation of scarce R&D resources is a central challenge for companies that have to cope with rapid change and fierce global competition. It was shown that there are two main forms of resource allocation that can be differentiated: The administrative, hierarchical allocation on the one hand and the allocation via internal markets on the other hand. In between there are a multitude of hybrid forms of resource allocation that are characterised by a mix of hierarchical and market-like elements.

Furthermore, it was explained that R&D activities are predominantly organised hierarchically. This means, for example, that the R&D budgets are determined top-down and the project selection as well as the corresponding allocation of resources is managed via central decision-committees – so-called steering committees (refer to chapter 4 and appendix 1).

As the literature review made clear, the application of internal markets can be an efficient alternative within the scope of R&D resource allocation. Whereas some authors emphasise the reduction of complexity, other authors attach great importance to the disciplinary effects of competition, the flexibility and the innovative power of market systems. Thus, the establishment of internal markets can offer valuable advantages to companies. So, for example, profit centers can adjust more flexible to potential changes in the environment, which on the other hand leads to an improved innovation climate and thus to high-quality goods and services.

Thus, internal markets can help to overcome the problems of the hierarchical resource allocation, since they are characterised by short communication and decision procedures and thus contribute to the reduction of information asymmetries. Moreover, they sanction opportunistic behaviour with loss of trust. Likewise, the establishment of internal markets leads to a heightened cost-consciousness and thus to an increased productivity and efficiency. Due to the high degree of decentralisation, the top-management is no longer engaged too strongly in the operative business and can concentrate more effectively on strategic tasks (Halal, Geranmayeh & Pourdehnad, 1993).

Despite the above-mentioned advantages of internal markets, particularly the research activities are further organised in a hierarchical way. This was also shown within the scope of the conducted exploratory case studies, which are presented in chapter 4. However, some companies already apply market-like elements in their resource allocation processes. Most common is the application of direct assignments; hereby the requesting divisions and/or business units give direct orders to the centralised research units. The statement of the Head of BASF-Research, in which he demands a “*market-oriented innovation process*” (Peitz, 2002 p.2), also emphasises the increasing importance of a more market-driven R&D resource allocation.

But, internal markets are not established standards in the R&D field and are largely unexplored so far. Merely Reger (1999) uses in his research paper the term ‘internal market’ in the context of R&D resource allocation. As he sees it, internal markets in R&D are characterised by the following three components: the organisational units are responsible for their own profits, they have autonomy of decision regarding clients and suppliers and there are internal inter-company prices. Since he states in his study that the R&D units of the companies are organised as cost centers a substantial condition for the operability of an internal market in the real sense of the word is missing, and therefore he calls the internal markets in his study “*quasi-markets*” (Reger, 1999 p.75). Likewise, it has to be noted that inter-company prices are predominantly determined top-down and are not the result of the direct interaction of supply and demand, as it is the case on ‘real’ markets. In addition, he does not consider the different characteristics of research activities on the one hand and development activities on the other hand; rather he speaks generally of R&D activities. Moreover, his results are merely based on a set of qualitative case studies.

The remarks made above illustrate that there is a need for a more detailed investigation of the topic 'internal R&D markets'. But, what does the presented literature review mean from the perspective of the present inquiry and what research questions can be derived from the relevant literature?

First of all the literature review illustrated that there is no uniform definition of the term 'internal market'. This was evidenced by a set of different definitions that are partly contradictory. In this way the literature review emphasised the necessity to develop a conceptual framework for the empirical studies, in which the term 'internal market' is clearly defined. This framework is presented in section 3.2 and was a major prerequisite for presenting valid and reliable research results.

In addition, the reviewed literature made clear that there are different kinds of R&D activities that need to be distinguished. Generally speaking, there are research activities on the one hand and development activities on the other hand. Accordingly, it is quite common that companies group their research activities in the research function and their development activities in the development function. Moreover, the literature review showed that companies categorise their R&D activities into different project types. In this study the following major types of R&D projects are distinguished:

- Research & Technology projects
- Projects for the development of new products and processes
- Projects for the enhancement of existing products and processes

As shown in the literature review, there are several characteristics that can be used to describe different types of R&D projects (e.g. degree of innovation, degree of uncertainty, time-to-market etc.). Moreover, the reviewed literature illustrated that these project types can be conducted in different organisational arrangements (centralisation vs. decentralisation). Furthermore, the cited literature showed that there are different forms of resource allocation that can be applied in order to allocate scarce resources on the different project types (hierarchy vs. market).

In this context it was also mentioned that the selected form of resource allocation can have major implications on the effectiveness and efficiency of the corresponding resource allocation processes. Therefore, there was a need to investigate project type-specific differences concerning the criteria mentioned above.

Consequently, the following research question was derived:

*RQ1: Are there differences across R&D project types concerning (1) the project characteristics, (2) the R&D organisation, (3) the R&D resource allocation, and (4) the allocation result?*

The investigation of these project type-specific differences should produce valuable information for the research inquiry in general. Moreover, these findings should provide the basis for a more detailed research on the applicability and favourability of internal markets in the R&D field.

As the literature review revealed, the application of internal R&D markets is still unexplored in R&D. Thus, there was a need to further investigate whether the application of market-driven forms of resource allocation is possible for all R&D activities or if it is only possible for certain project types. To clarify this general aspect the following research question was stated:

*RQ2: For which types of R&D projects are market-driven forms of resource allocation possible?*

The most challenging question, however, is to select the most effective and efficient form of resource allocation for the respective project types (hierarchical resource allocation vs. market-driven resource allocation). In this context the presented literature review provided a sound theoretical base (refer to section 2.4), not only for the assessment of the applicability but also for the judgement of the favourability of market-driven forms of resource allocation. Therefore, the presented theoretical concepts are closely related with the following research question:

*RQ3: For which types of R&D projects are market-driven forms of resource allocation more effective and/or efficient than hierarchical forms of resource allocation?*

The answers to the research questions mentioned above should produce novel insights concerning the state of the art of R&D resource allocation. Thus, the research findings of this inquiry should be valuable for the scientific community, but also for practitioners. Since the author claimed that the research findings of this study are of high practical relevance there was a need to develop guidelines, in form of policy recommendations (see section 7.2), on how to design an internal R&D market in practice. In this context the following additional research question was of major interest:

*RQ4: How should an internal market within R&D be designed?*

Given the presented research questions mentioned above, the following chapter explains the methodological approach that was applied in order to answer these questions.

## **3 Methodology**

### **3.1 Introduction**

A brief description of the underlying research methodology was already presented in section 1.3. In this chapter the methodological approach is discussed in more detail.

In a first step, a conceptual framework is developed in section 3.2. Since a specific theory concerning ‘internal R&D markets’ didn’t exist in the literature it was necessary to develop a framework before starting with the empirical studies (Schnell, Hill & Esser, 1989; Marshall & Rossman, 1999). On the basis of the reference model ‘external markets’ the main market elements are identified, in order to discuss them subsequently in the context of the internal R&D resource allocation. Based on this analysis the term ‘internal R&D market’ is defined.

Section 3.3 discusses the data requirements associated with the present investigation, both, from a qualitative and a quantitative perspective. Moreover, the related conceptual and operational problems when seeking to collect these data are discussed.

Given this, a mixed-method approach appeared to be appropriate for the research inquiry. The advantages and challenges of this approach are explained in section 3.4. Moreover, it is outlined that a sequential triangulation of research methods was used throughout the inquiry, including case study research, survey research, and group interviews. In this context it is also discussed how other researchers of this topic have undertaken their investigations, particularly what in their work had potential for the present investigation.

The following section 3.5 is concerned with a detailed description of the conducted case study research. A first sub-section presents definitions and discusses the applicability of case studies. A further sub-section then deals with the design and implementation of the case studies within the exploratory stage of the present investigation.

Thereafter, the methodological procedure regarding the international survey is described in section 3.6. First, the underlying research model is shown, which illustrates the central hypotheses that should be tested within the scope of the survey. Moreover, the research arrangements and instruments as well as the investigation objects are discussed.

Section 3.7 explains the procedures associated with the group interviews that were conducted at the end of the research, in order to validate and verify the research findings as well as to derive policy recommendations.

Eventually, section 3.8 is concerned with the ethical issues and the delimitations of the thesis.

Finally, section 3.9 discusses the methodological limitations associated with the research inquiry and the implications these limitations have with regard to the research findings.

## 3.2 Conceptual framework

### 3.2.1 Research problem and research questions

The research problem was discussed in detail in section 1.1. However, it seems to be useful to re-identify the general problem at this juncture.

Within R&D the following economic problem emerges: How could and should scarce resources (human resources, funds etc.) be allocated between competing projects?

If structures and processes in R&D are in line with the strategy of the enterprise and market needs, costs can be avoided, products can be launched earlier and thus higher profits can be obtained. Therefore, it is of increasing importance to allocate existing scarce resources (personnel, material, capital etc.) to those R&D projects, which promise the highest value contribution for the company (Foster, 1986).

Fundamentally, two forms of resource allocation can be differentiated: On the one hand the centralised administrative allocation by an instruction-authorised instance (hierarchy) and on the other hand the market-driven allocation via a completely decentralised coordination between equal partners (market).

Despite the potential advantages of market-like solutions a rather hierarchical, administrative organisation still prevails in R&D. Thus, the present investigation explores the possibilities of applying market-driven forms of resource allocation within the R&D context.

Given this, the following central research questions can be identified:

*RQ1: Are there differences across R&D project types concerning (1) the project characteristics, (2) the R&D organisation, (3) the R&D resource allocation, and (4) the allocation result?*

*RQ2: For which types of R&D projects are market-driven forms of resource allocation possible?*

*RQ3: For which types of R&D projects are market-driven forms of resource allocation more effective and/or efficient than hierarchical forms of resource allocation?*

*RQ4: How should an internal market within R&D be designed?*

Since the term ‘market-driven resource allocation,’ respectively, ‘internal market’ is not clearly defined in the existing literature there was a need to develop a conceptual framework before embarking on the empirical studies.

### **3.2.2 Necessity to develop a conceptual framework for the empirical studies**

As it was shown in the literature review, there is no uniform definition of the term 'internal market'. Rather there exist a set of different definitions that are partly contradictory (see section 2.3). Thus, it was necessary to develop a framework for the empirical studies, in which the term 'internal market' is clearly defined. Without such a framework valid and reliable research results cannot be achieved (Schnell, Hill & Esser, 1989; Marshall & Rossman, 1999).

Since the creation of internal markets is nothing else than the reconstruction of the free enterprise system within an enterprise (Lehmann, 2002), the theory of external markets appeared to be the most suitable reference model for the investigated topic (see section 3.2.3). On the basis of this reference model the main elements of a market were initially defined. Afterwards these elements were transferred to the prevailing research context (see section 3.2.4).

This means that each element was scrutinised with regard to the internal R&D resource allocation. Based on the insights of this transfer a definition of an internal R&D market was developed that ensured a uniform understanding of the term (see section 3.2.5). The development of such a framework was crucial for the efficient implementation of the empirical studies.

### **3.2.3 Reference model: External markets**

The implementation of internal markets is the attempt to reconstruct elements and principles of market economies within an enterprise (Lehmann, 2002). Thus, it is necessary to take a close look at the characteristics of external markets. With the help of the reference model 'external markets' it can be clarified what actually should be reconstructed within the enterprise. In this context the neoclassical approaches, in which the functioning of competitive markets is in the center of attention, can serve as the basis for the general understanding of market systems (see section 2.4.2).

The system 'external market' can be characterised by a set of elements that are interrelated (Bertalanffy, 1951). Concerning these relationships, markets are characterised by decentralised exchanges between economic actors. In case the exchanges are successfully they result in transactions and comprise negotiations, the terms of the exchange as well as the physical transition of the transaction objects. Indispensable precondition for market-driven exchange processes is the existence of adequate infrastructure. On the one hand this infrastructure builds the framework for making first contacts as well as for the subsequent contract negotiations (communication channels) and on the other hand it provides the conditions for the physical execution of transactions (logistical channels). In this way the infrastructure sketches out the space for potential interactions between concrete transaction partners, which aim at mutual exchanges of goods or services, respectively, the exchange of goods or services for money. Furthermore, market-driven exchanges

are characterised by the existence of relative or absolute prices that must be paid for the transaction objects (Hayek, 1969; Luhmann, 1988; Fritsch, Wein & Ewers, 1996).

Beside the described relationship component it is also important to investigate the requirements of market-driven systems regarding the included number of elements and their characteristics. Fundamentally, all economic subjects that have the ability and the willingness to enter exchange relationships with other market participants are elements of the system 'external market'. Within the scope of market-driven exchange relationships at least two decision units must exist. But, for the functioning of markets the existence of one supplier and one requestor is not sufficient. Only if there is some form of competition within markets, they can fulfil their allocation-, coordination- and motivation function (see section 2.4.2). In this context one has to notice that it is essential that the market participants have the right of disposal (see section 2.4.3) and are in charge of different resources before they enter exchange relationships. This aspect is important since transactions aim at increasing the individual economic utility of the market participants. An exchange of similar resources is in principle conceivable; however, this would be economically absurd since the utility of the involved parties will decrease due to the existence of transaction costs (see section 2.4.4). Depending on the number of participants on each market side different market types, such as monopoly, oligopoly and polypoly, can be distinguished that are characterised by different competitive intensities (Stackelberg, 1992).

Moreover, further economic subjects are required that are mainly concerned with the establishment and the maintenance of an operative market system, respectively, with the improvement of efficiency of the exchange processes. Thus, there are governmental but also non-governmental institutions that issue fundamental restrictions within market systems. Also they supervise market transactions and impose the set up regulations as well as they sanction inappropriate behaviour of market participants (Picot, Dietl & Franck, 1999). Further important elements of external markets are economic subjects that are involved in the exchange processes in order to ensure an efficient processing. These subjects function as mediators between suppliers and requestors.

In addition to that the involved parties are hierarchically independent of each other. This means that neither the supplier nor the requestor of a good or service is legitimated to give binding instructions to the other party. This illustrates the freedom of all economic actors within the scope of the free enterprise system (Peacock, 1989). This freedom leads to the fact that the acting decision units base their exchange decisions exclusively on their individual preferences. Interests of the society take second place behind the individual interests. A further essential element of external markets is the right to appropriate the resulting profits from a transaction in order to satisfy further material or immaterial needs.

The above-mentioned elements and relationships of free market systems can be brought together in order to develop the following definition:

An external market requires:

- the existence of several market actors (at least one supplier and one requestor each)
- that are competing with each other (competition),
- and are in charge of different (material or immaterial) resources,
- and are hierarchically independent,
- and carry out transactions via adequate infrastructure,
- according to their individual preferences
- by taking into consideration the (negotiated) prices
- of the corresponding transaction object (good or service),
- and have the right to fully appropriate the resulting profits from these transactions.

### 3.2.4 Market-like elements within R&D resource allocation

On the basis of the reference model 'external market' it shall now be investigated to what extent the different elements of the definition stated above can actually be reconstructed and how they can be organised within the context of the internal R&D resource allocation. However, one has to bear in mind that in practice very few firms reconstruct all elements of external markets within an enterprise. Thus, the quasi-market character of internal R&D markets must be taken into consideration (Reger, 1999).

#### Existence of several market actors

As already mentioned, markets in contrast to hierarchical, administrative approaches are characterised by several actors (suppliers and requestors) that offer or request certain goods or services. Often so-called mediators are involved in this process. To establish a market relationship at least two market participants (one supplier and one requestor each) are needed; this case is called bilateral monopoly<sup>30</sup>.

In the R&D field there often prevail oligopolistic market structures, where a few suppliers and a few requestors are confronted with each other (Tirole, 1993; Varian, 1994). Oligopolistic scenarios are often characterised by a high degree of complexity since strategic interactions take place between different actors of a market side (Peters, 2002). In the extreme case, it may also occur that the central

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<sup>30</sup> In a bilateral monopoly the outcome is indeterminate and depends on negotiation and bargaining power. Fundamental bargaining models are discussed by Nash (1951) and Selten (1977).

research unit is the only supplier of a certain R&D project and that the results from this project can only be used by one division. The ‘hold-up problem,’ described in section 2.4.5.2, is the result of such a bilateral monopoly. Likewise, there are cases conceivable, in which several units which are close to the market (e.g. marketing companies) request similar R&D services from a number of potentially supplying R&D units.

For the establishment of real market relationships it is required that the single R&D units have the decision competence concerning the use of the resources, which are needed for the exchange processes between the involved units. In this way market-like regulations can lead to an improved orientation of single decisions on the company’s objectives that are of overriding importance (Lehmann, 2002).

### **Competition**

As stated before, the element ‘competition’ is a crucial factor for the functioning of markets. A competitive market is characterised by the competition of the involved actors that are trying to negotiate lucrative transactions (Peters, 2002). Depending on the number of suppliers and requestors a set of market forms can be distinguished. The corresponding negotiation power of the actors plays an outstanding role in this context (Knieps, 2001).

As described above, it can occur, in the extreme case, that one R&D supplier is confronted with one R&D requestor. Thus, the competition in internal R&D markets can be rather low in some cases. The market functions of allocation, coordination and motivation cannot unfold their full effect in one-to-one situations and thus it can lead to market failures in consequence (see section 2.4.2.4). Hence, a negotiation solution or a hierarchical solution with the involvement of a regulative authority appears to be favourable in this specific situation. However, the majority of the R&D projects is characterised by a larger number of potential market participants than just two.

For the regulation of competition there are a multitude of features available to the management in this context. The following alternatives – each discriminated regarding the supplier side and the requestor side – can be taken into account:

- Renouncement of competition; this means establishment of binding regulations for the processing of exchange relationships between certain internal transaction partners;
- Limited competition; this means the possibility to freely choose among different internal suppliers and requestors;
- Free competition; this means the possibility to carry out transactions with economic subjects from the external market (in addition to the internal subjects).

As the empirical findings illustrate, there still exists free competition in many companies concerning the purchase of R&D services (see appendix 1); this means the requesting units have the general allowance to purchase the required R&D services from external suppliers. However, due to the specific characteristics of R&D services (see section 2.1) the possibility to find an adequate external supplier can be described as rather limited.

Regarding the supply of R&D services, there is a more limited competition since the supplying R&D units are normally not allowed to offer their services to potential external requestors. This is the case because of nondisclosure aspects and in order to secure competitive advantages.

In this context the management or a specific authority is assigned to supervise the market actions. This supervision is essential for the functioning of internal markets in order to prevent the abuse of power or to ensure the compliance with laws, contracts, guidelines and norms.

### **Different resources**

The entering of exchange relationships only increases the utility of the involved units if they are in charge of different resources in order to produce certain transaction objects. This situation can usually be attributed to the following reasons: The involved units resulted from an action-oriented segmentation of the enterprise task; this means that the potential customer does not have all the necessary competencies to produce all the required input factors in order to fulfil his tasks; rather he is partly dependent on preliminary work of other units. The different equipment with resources thus results from the organisational structure. In the R&D context this is the case because of the organisational separation of research activities on the one hand and development activities on the other hand (see sections 2.2 and 4.3). Thus, certain products, as for example drugs, can only be developed after some preliminary research activities have been conducted.

The entering of market-driven exchange relationships, however, can also be of advantage if the required competencies are available in the requesting unit. This is the case since the purchase of a certain R&D service from an internal supplier can be accompanied by qualitative and cost advantages. Especially in the R&D field there are huge differences concerning the available resources within the single units (e.g. specific expertise or superior technologies). These differences can be utilised in the best way by the means of market-driven exchange relationships.

### **Hierarchical independence**

Since the concept of internal markets should serve as an alternative to central plans, that are turned into practice with the help of binding instructions, no further reason is needed for the fact that the application of internal markets is limited to those units which are hierarchically independent. The participants in internal R&D markets are thus meant to be equal partners. This is also underpinned by Reger

who states that the participants in internal markets “*have autonomy of decision regarding clients and suppliers*” (Reger, 1999 p.75). In general, internal markets can be interpreted as hierarchically independent ‘islands’ within the hierarchically structured system ‘enterprise’ (Lehmann, 2002).

### **Processing transactions via adequate infrastructure**

Transactions are the central criterion for the differentiation between market-driven and non-market-driven forms of relationships. Following Lehmann (2002) the thesis in hand is based on the following understanding of the term transaction:

Transactions describe:

- processes of the transfer of one or several rights of disposal for goods or services (see also the remarks on property rights in section 2.4.3),
- from the initiation up to the processing of the contractual specified activities (Picot (1982) discusses the corresponding phases of transactions),
- between equally ranked units,
- that are reciprocal (this implies the determination of an absolute or relative price; see also Kirzner, 1973 and Plinke, 1996),
- but must not necessarily occur on a voluntary basis (under certain circumstances it can be opportune for a company to issue restrictive regulations that tell the divisions with which transaction partners they are allowed to deal).

If the original transfer of a good or service results in a payment in return, than it is about a market-driven relationship; or more precisely it is about a transaction. However, in case the requesting unit does not have to make any payment in return, than it is about a non-market-driven relationship. Within the scope of transactions the market participants interact by negotiating the terms of exchange. Beside the price that the requestor has to pay these negotiations are mainly concerned with the nature and the features of the traded good or service.

For the efficient processing of these negotiations the market participants need information about their counterparts of the other market side. But often information deficits exist. For example, this is the case if unit A has information that is of interest for unit B in order to fulfil a certain task, but the relevant information is not available in unit B. The main instrument for the elimination of those information deficits is communication. This communication reaches from structured, periodical communication (e.g. quarterly report of a limited company), via specific marketing measures (e.g. advertising or product catalogues), up to unstructured, irregular communication (e.g. in form of so-called success stories). Moreover, a market place is required. This can be a certain place at a certain time, as in the case of a weekly market. However, in times of the Internet virtual, time-independent market places play an increasingly important role (Miller & Morris, 1999).

The use of modern information and communication technologies, as the Intranet (Block, 1999; Horn, 1999; Peters, 2002), appears to be an adequate infrastructure for the processing of transactions via internal R&D markets (see chapter 4, chapter 6, and appendix 1). Thus, the Intranet provides a suitable platform to generate and distribute information and it simultaneously serves as an additional communication channel for the market participants. Likewise, it serves as a logistical channel, from the gathering of information via the initiation and conducting of negotiations up to the subsequent settlement and the transfer of the services. Moreover, it could serve as a platform for an intranet-based auction design, which constitutes a further area for research (refer to chapter 6 and section 7.3).

### **Individual preferences**

The question on which objectives the decisions of decentralised units should be oriented is one of the biggest challenges within the context of establishing internal markets. External markets owe their efficiency mainly to the fact that all economic actors act in accordance with their individual preferences. Thereby the pursuance of the individual self-interest of the actors is only restricted in cases where the freedom of other market participants is affected. The realisation of the objectives of the total system, as for example the increase of the public welfare, is merely a by-product that results from the pursuance of the corresponding individual interests and thus it is not an independent value within the system of objectives of the involved actors.

However, the implementation of internal markets follows completely different prerequisites since the favourability of decisions must always be evaluated concerning their contribution to the achievement of the company's objectives (e.g. increase in market capitalisation).

On this basis the following two demands can be derived for the design of internal markets:

- On the one hand the objectives of the single units must be in line with the company's objectives; this means that improvements in profitability of the respective units should lead to corresponding positive effects from the company's point of view. This demand implies a profit center organisation.
- On the other hand adequate measures must be taken in this context in order to bring the preferences of the single decision-makers in accordance with the unit's objectives and thus with the company's objectives (refer to principal agent theory in section 2.4.5). In the practical design of internal markets this can be achieved by implementing incentive systems. Thereby the respective realisable individual utility is combined with the monetary results of the corresponding unit via profit-sharing agreements.

The compliance with these demands is particularly difficult in R&D contexts due to the following reasons:

- In contrast to external markets, internal R&D markets are not about the sale of consumers' products but producers' products. This in turn has implications on profit responsibility which again has implications on incentives.
- The research units are under normal circumstances not profit responsible; this means that they are cost centers and thus only responsible for costs and the efficient use of budgets.
- Because of the partly missing profit responsibility (especially in the research function) and the general difficulty to measure the success of innovation activities it is difficult to conceptualise a commonly accepted incentive system. (Specht & Beckmann, 1996).
- The improvements in profitability due to the R&D activities can not be directly measured. This is particularly the case because of the fact that it always takes a certain time period before the conducted R&D activities show positive effects (Twiss, 1994).

The remarks made above emphasise the importance of incentive systems and principal-agent relationships (see section 2.4.5). The involved market participants have to have the same objectives as the firm in aggregate. Thus, internal R&D markets need to be regulated by top-management. Then the market participants can make their offers and bids in order to maximise value (e.g. via face-to-face negotiations or an intranet-based auction).

The statements made above also illustrate the quasi-market character of internal R&D markets. Moreover, they show that the development of an adequate incentive system constitutes a further research opportunity within the context of internal R&D markets (see section 7.3).

### **Existence of prices**

Within the scope of internal exchange relationships transfer prices function as a standard of value for the exchanged scarce resources (Milgrom & Roberts, 1992).

As resources that can be evaluated by transfer prices can be considered:

- potential factors (e.g. fixed-assets or the performance of co-workers),
- consumption factors (resources and auxiliary material), or
- possibly marketable intermediate products and services.

In the wider sense transfer prices describe all stated values that are built for reasons of an efficient use, steering and allocation of resources (Tang, 1993).

According to Hellwig (1993) transfer prices can be built for:

- production factors,
- internal services,
- funds, or
- for the exchange of services between affiliates.

The underlying understanding of the term ‘transfer prices’ (in the narrower sense) refers to goods or services that are traded within the scope of internal transactions (Emmanuel, 1977; Gietzmann, 1984).

With the help of transfer prices the monetary impact of the exchanges for the involved units can be made explicit:

- for the internal suppliers the transfer prices serve as a means for the evaluation of the attained revenues,
- for the internal requestors transfer prices serve as a means for the evaluation of the incurred costs.

In contrast to external market prices, transfer prices are not necessarily the result of a bargaining process between the transaction partners or the result of a multitude of isolated decisions under competitive conditions. Rather it is a question of market-oriented or cost-oriented prices. Likewise, it is possible that the prices are determined by the management.

As a point of contact of market-oriented prices serve prices to which the same or similar goods or services are traded between independent actors on external markets. If on external markets a standardised price cannot be identified or if the price level is very volatile, average prices can serve as the basis for internal transactions. Since no or relatively low sales costs are incurred by internal transactions the market-oriented prices have a discount compared with the actual external market prices.

Cost-oriented prices on the other hand are calculated according to the consumed resources. Thus, these prices are usually only cost-covering. Moreover, an adequate profit markup can be added to the cost-oriented prices in order to give the internal suppliers the possibility to make their own profits.

In R&D contexts, particularly in the research function, it is often the case that there is no settlement of transfer prices. In these cases the R&D projects are financed by the group (corporate funds). However, for the predominant part of the R&D activities transfer prices are settled. Most often these prices are cost-oriented and merely cost-covering. Under these circumstances the supplying units do not make any profits. In this context it is apparent that the research units are normally organised as cost centers whereas the development units are normally organised as profit centers since they are assigned to certain decentralised and profit responsible divisions/business units (see chapter 4 and appendix 1).

Within the scope of an internal R&D market the prices for transaction objects could either be negotiated between the involved parties or possibly be determined via an intranet-based auction design. In section 2.4.2.4 the four major forms of auction ('English auction,' 'Dutch auction,' 'First Price Sealed Bid auction' and 'Vickrey auction') were introduced and explained. But which form of auction is most efficient for the allocation of scarce R&D resources? This question can be answered on the basis of a transaction cost theoretical evaluation (refer to section 2.4.4). From view of transaction cost theory one should choose the form of auction that incurs the lowest transaction costs. However, it is extremely difficult and time-consuming to exactly measure and quantify the transaction costs associated with a certain form of auction. Thus, it is recommendable to estimate the relative level of transaction costs on the basis of the respective communication and information requirements.

Based on the remarks made in section 2.4.2.4 Table 1 gives an overview of the communication and information requirements of the relevant forms of auction.

<b>Auction form</b>	<b>Communication requirements</b>	<b>Information requirements</b>
English auction	high	not existent
Dutch auction	very low	very high
First Price Sealed Bid auction	very low	very high
Vickrey auction	very low	not existent

**Table 1: Comparison of alternative forms of auction**

On the basis of a transaction cost theoretical evaluation it can be concluded that the use of a 'Vickrey Auction' is most suitable in R&D contexts, since this auction model has the comparably lowest communication and information requirements and thus incurs the lowest transaction costs.<sup>31</sup>

### **Transaction objects**

Transaction objects are the main prerequisite that actually market-driven exchange relationships can take place. Transaction objects can be material goods as well as immaterial goods, such as, for example, services or intellectual property (see section 2.4.3). A further feature of transaction objects is the homogeneity or the heterogeneity. Whereas on spot markets clearly defined homogeneous goods are traded (e.g. commodities, oil etc.), there are also markets on which partly hetero-

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<sup>31</sup> It has to be noted that the design of an auction model for the internal R&D resource allocation is beyond the scope of this thesis and thus provides a further potential starting point for future research (see section 7.3).

geneous goods are traded that are difficult to define. As an example for such a market can serve the B2B market place of 'yet2.com' on which R&D services are supplied and requested (URL: <http://www.yet2.com>).

Within the scope of internal R&D markets the transaction objects are:

- Intellectual property,
- Ideas,
- R&D services and/or R&D projects, and
- R&D results.

Due to the high knowledge intensity the predominant part of the R&D services and R&D projects can be described as immaterial and heterogeneous transaction objects. R&D services and R&D projects are thus mainly concerned with abstract factors, such as knowledge for the solution of problems or information about the needs and preferences of the customers. This leads to the fact that R&D activities are characterised by a high degree of complexity, out of which difficulties result concerning the requestor's assessment of the respective utility of certain R&D services or R&D projects.

The future economic impacts that result from purchasing certain R&D services or R&D projects are not clearly evident and cannot be easily evaluated. Thereof follows a high need of explanation of R&D services and R&D projects as well as an asymmetric distribution of information between supplying and requesting units (refer to section 2.4.5). With that directly combined are difficulties in measuring the output quality, which leads to a high level of uncertainty by the requesting units concerning the quality aspects. Arrow (1986) describes this problem as hidden characteristics. As a rule the satisfaction of needs that result from a R&D service or R&D project can be only evaluated *ex post* (if at all).

### **Profit appropriation right**

The motivation of economic actors on external markets to enter into transactions, to improve the efficiency of processes or to develop innovative solutions comes mainly from the right to fully appropriate the resulting profits. In this context contracts serve as legal grounds and thus provide the basis for transactions between suppliers and requestors. With the earned profits replacement investments or expansions can be financed or further needs can be satisfied. Thus, acting in an economic, rational way results in a direct or indirect improvement of the individual level of utility.

Within the scope of internal market systems the criterion of profit appropriation is not easily fulfilled. Often the earned profits don't remain in the units that gained them, but will be redistributed in the course of centralised investment decision processes according to certain performance measures. An overview of the most relevant performance measures in R&D contexts is presented by Specht & Beckmann (1996). To increase the motivation to transact on internal markets it is im-

portant to transfer the profit responsibility to the respective units and their decision-makers and to offer a share in profits to the involved co-workers. This implies a profit center organisation as well as an adequate incentive system (Milgrom & Roberts, 1992). But, one has to bear in mind that in most companies the research units are organised as cost centers. This again underpins the quasi-market character of internal R&D markets.

### 3.2.5 Summary and resulting definition of an internal R&D market

In summary it may be said that not all elements and features of external markets can be transferred problem-free to the internal R&D resource allocation. Thus, internal R&D markets can be described as quasi-markets. Moreover, it was emphasised that, within the context of internal market relationships, the objectives of the decentralised units must be matched with the company's objectives.

As it was shown, the implementation of internal markets is nothing else than the attempt to reconstruct elements of a free enterprise system within an enterprise. However, it was also mentioned that in practice very few firms reconstruct all elements of external markets within an enterprise. Thus, the developed conceptual framework needed to make concessions to reality, i.e. to the quasi-market character of internal R&D markets. Nevertheless, the basic reference model 'external market' was suitable for the identification and description of the elements that characterise markets. Based on this analysis the following main aspects of an internal R&D market (or better quasi-market) can be defined:

An internal R&D market is:

- an (electronically) platform (market place)
- that is regulated by the management (supervision)
- and on which internal R&D suppliers and R&D requestors (actors) with equal rights (hierarchically independent)
- that are in charge of different resources
- carry out transactions (exchange processes)
- within the scope of a (communicative) competition
- according to their individual preferences (value-maximisation)
- by taking into consideration the (negotiated or auctioned) prices for intellectual property, ideas, R&D services and/or R&D projects or R&D results (transaction objects)
- and have the right to fully appropriate the resulting profits from these transactions due to informal or formal contracts (profit responsibility).

These aspects will serve as a basis for the further discussion concerning internal R&D markets. However, one has to keep in mind that not all of these aspects must be fulfilled when talking about a market-driven resource allocation. For example, the management board passes on strategic guidelines within them the market participants can make decisions according to their individual preferences. Or, in the extreme case, an internal market exchange relationship can occur between only two actors, namely one supplier and one requestor.

However, it has to be noted at this juncture that most of the cases have one or very few supplying R&D units but few or many potential users. Since the resources of the R&D units are limited there is a need to allocate these resources to those R&D projects that contribute the highest value to the company. A potential solution to this problem could be an intranet-based auction design, as illustrated in this work.

In conclusion, the possibilities for the design of an internal R&D market are manifold. Nevertheless, the developed definition of the term ‘internal R&D market’ provided a suitable framework for the conducted empirical studies. The following section is concerned with the data requirements associated with this framework.

### **3.3 Data requirements**

#### **3.3.1 Qualitative data**

After the development of the conceptual framework it was decided what data needed to be collected. Given the exploratory character of the study, it appeared to be appropriate to start with qualitative research in order to get a picture of the topic-related issues and to clarify the taxonomy (e.g. types of R&D projects, market-driven resource allocation, effectiveness, efficiency etc.). Therefore, a set of case studies in technology-intensive companies was conducted (see section 3.5).

Based on the findings of the literature review (chapter 2) and the developed conceptual framework (section 3.2) an interview guide was developed (see appendix 1), which provided the basis for semi-structured in-depth interviews with R&D experts. The design and implementation of the case study research is discussed in more detail in section 3.5.2.

Given the central research questions of the inquiry the case studies focused on two main aspects:

- HOW are scarce R&D resources allocated on different types of R&D projects?
- WHY are the resource allocation processes organised in this way?

The case studies should provide a rich set of qualitative data, which documents the current status of the R&D resource allocation as well as potential starting points for the application of internal market mechanisms in the R&D field.

Main emphasis had the following four aspects:

- Types of R&D projects,
- R&D organisation,
- R&D resource allocation, and
- Allocation result.

The analysis of the raised qualitative data provided the basis for the derivation of hypotheses and the design of a concise questionnaire for the subsequent survey stage (see section 3.6).

Additional qualitative data were raised by conducting a set of semi-structured group interviews. These data were required in order to validate and verify the findings of the survey (Wass & Wells, 1994). Moreover, the group interviews helped to derive policy recommendations (see section 7.2) and to get at the meaning behind some of the research results. The procedures associated with these group interviews are discussed in detail in section 3.7.

As illustrated above, the qualitative data played an important role for the present investigation. However, there are some operational problems one has to consider when dealing with qualitative data. In this context Saunders, Lewis & Thornhill (2003) mention the following data quality issues:

- forms of bias,
- validity,
- reliability, and
- generalisability.

The two main forms of bias related to qualitative research interviews are interviewer bias and interviewee or response bias (Easterby-Smith, Thorpe & Lowe, 2002).

The term validity, in this context, “*refers to the extent to which the researcher gains access to their participants’ knowledge and experience, and is able to infer a meaning that the participant intended from the language that was used by this person*” (Saunders, Lewis & Thornhill, 2003 p.253).

In the context of qualitative research reliability is concerned with whether other researchers would reveal similar information (Healey & Rawlinson, 1994; Easterby-Smith, Thorpe & Lowe, 2002).

Furthermore, one has to be aware that qualitative research does not allow the researcher to make generalisations about the entire population (Yin, 1994).

Given the operational problems associated with qualitative research methods, it became clear that additional quantitative data would be beneficial to the inquiry. Thus, the following section deals with the data requirements associated with quantitative approaches.

### 3.3.2 Quantitative data

In order to gather quantitative data which were required for hypothesis-testing it appeared to be suitable to conduct a written postal survey. Questionnaires were sent to 281 huge R&D-intensive companies worldwide, which were mainly selected from the Fortune Global 500 Database. The sampling procedure is described in section 3.6.3. In this way it was possible to make generalising statements concerning the topic 'internal R&D markets'.

Unlike the qualitative approaches discussed above, the questions asked in questionnaires need to be defined precisely prior to data collection. In contrast to semi-structured in-depth interviews, prompting and exploring issues further is not an option in survey research. *"In addition, the questionnaire offers only one chance to collect the data, as it is often difficult to identify respondents or to return to collect additional information."* (Saunders, Lewis & Thornhill, 2003 p.286). This illustrates that there was a need to define precisely what data needed to be collected and how to analyse them. In this context the design of the questionnaire had main emphasis in order to answer the research questions and to meet the research objectives.

Due to the exploratory character of the inquiry the collected quantitative data were mainly used for descriptive purposes, although it was intended to examine differences between R&D project types. This is, the survey aimed at exploring the project type-specific differences concerning (1) the project characteristics, (2) the R&D organisation, (3) the R&D resource allocation, and (4) the allocation result. Given this, the project type was the dependent variable, whereas the variables associated with the factors mentioned above were the independent variables. The assumed relationships were expressed in the following central hypotheses:

- There are differences across R&D project types concerning the project characteristics.
- There are differences across R&D project types concerning the R&D organisation.
- There are differences across R&D project types concerning the application of market-driven forms of resource allocation.
- There are differences across R&D project types concerning the effectiveness and/or efficiency of market-driven forms of resource allocation.

These hypotheses were refined on the basis of the case study research (see section 4.6) and were tested through statistical analysis. However, before the actual test of these hypotheses there was a need to clarify the way in which the variables

can be measured. In this context Dillmann (2000) distinguishes between the following three types of data variable that can be collected through questionnaires:

- opinion,
- behaviour, and
- attribute.

In general, the type of data influences the way in which questions are worded. While opinion variables record how respondents feel about something or what they think or believe is true or false, behaviour and attribute variables record what respondents do and are (Saunders, Lewis & Thornhill, 2003).

In the present investigation most variables can be classified as opinion variables since the responses of the R&D experts reflect their attitude concerning carefully constructed statements that range from very positive to very negative. The questions of the designed questionnaire were highly standardised and were formulated as fixed-alternative questions. If possible, a five-point ordinal Likert scale was applied (Likert, 1932). By applying this scaling method the comparability of the raised quantitative data was increased.

Furthermore, most authors classify quantitative data into different data types (see for example Diamantopoulos & Schlegelmilch, 1997; Morris, 1999). In general, quantitative data can be divided into two groups (Saunders, Lewis & Thornhill, 2003):

- categorical data
- quantifiable data

Categorical data can be further subdivided into descriptive (nominal) and ranked (ordinal) data; and refer to data whose values cannot be measured numerically. Often these data are classified into categories according to the characteristics in which the researcher is interested or they are placed in rank order.

On the other hand, quantifiable data can be numerically measures as quantities. It can be stated that quantifiable data are more precise than categorical because the researcher can assign each data value a position on a numerical scale. Quantifiable data are further subdivided into continuous and discrete data. Whereas continuous data are those whose values can theoretically take any value provided that you can measure them accurately enough (Morris, 1999), discrete data can, by contrast, be measured precisely.

In this context Zikmund (2002) distinguishes between nonmetric (nominal or ordinal) and metric (interval or ratio) scales. A nominal scale is a measurement scale of the simplest form. It assigns letters or numbers to objects, which serve as labels for identification or classification. An ordinal scale, however, is a scale that arranges objects or alternatives according to their magnitudes.

Concerning the level of measurement of quantifiable data, Zikmund (2002) distinguishes between interval scales and ratio scales. He points out that interval scales do not only arrange objects or alternatives according to their magnitudes but also distinguish this ordered arrangement in units of equal intervals. By contrast, a ratio scale is a scale that measures absolute rather than relative quantities and possesses an absolute zero.

The different levels of numerical measurement dictate the range of techniques that can be applied for data analysis. In accordance with Zikmund (2002), Table 2 shows the appropriate descriptive statistics for each type of scale.

Type of Scale	Numerical Operation	Descriptive Statistics
Nominal	Counting	Frequency in each category, percentage in each category, mode
Ordinal	Rank ordering	Median, range, percentile ranking
Interval	Arithmetic operations on intervals between numbers	Mean, standard deviation, variance
Ratio	Arithmetic operations on actual quantities	Geometric mean, coefficient of variation
Note: All statistics that are appropriate for lower-order scales (nominal is the lowest) are appropriate for higher-order scales (ratio is the highest).		

**Table 2: Descriptive statistics for types of scales**

As mentioned above, the predominant part of the scales applied in the questionnaire had five-point ordinal Likert scales. Thus, the descriptive analysis focused mainly on counting frequencies or calculating percentages for the different types of R&D projects. In this context cross-tabulations appeared to be most appropriate, with the categorical dependent variable ‘project type’ on the one hand and the respective ordinal independent variable on the other hand. To test the differences between the different types of R&D projects a set of chi-squared tests was conducted. The applied statistical procedures are discussed in more detail in section 3.6.3.

The remarks made above illustrated the data requirements associated with the present investigation. Moreover, it was explained that there were several operational and conceptual problems that needed to be solved, in order to get valid and reliable research results. The solution to these problems is the application of a mixed-method approach, which is described in the following section.

### 3.4 Mixed-method approach

Qualitative and quantitative approaches do not exist in isolation. By omitting qualitative methods, the researcher may overlook many phenomena that occur within the context of the setting. Shaddish, Cook & Leviton (1991) note that quantitative measurements rest on qualitative assumptions about which constructs are worth measuring and how constructs are conceptualised. By omitting quantitative methods casual relationships between variables as well as quantification and analysis of those variables to determine statistical probabilities and certainty of a particular outcome will be absent. Thus, it can be stated that the weaknesses of each method are balanced by the strengths of the other methods.<sup>32</sup>

Thus, it is often beneficial to combine qualitative and quantitative methods (triangulation) in the same study (Saunders, Lewis & Thornhill, 2003). In triangulation, one needs to consider whether a set of data collected by different research methods can be used to complement or contribute to or confirm findings based on other research methods. In other words, multi-method approaches aim at providing complementary data sets which together give a more complete picture than can be obtained by using either method singly (Tripp-Reimer, 1985).

Given the research questions and objectives of the inquiry a mixed-method approach appeared to be suitable. The main benefits of such an approach are (Easterby-Smith, Thorpe & Lowe, 2002; Collis & Hussey, 2003):

- that it increases the validity and reliability of the findings by allowing the researcher to examine the same phenomenon in different ways, and
- that it promotes greater understanding of the findings, i.e. quantitative data can show that change occurred and how much change took place, while qualitative data can help you understand why.

Concerning the present investigation, the following further advantages were associated with the use of triangulation (Duffy, 1987 p.132):

- Qualitative data gained from the case study research were used as the basis for selecting survey items to be used in instrument construction.
- The understanding from the case studies supported the interpretation of the statistical survey results.
- Quantitative survey results were validated and verified by results obtained through qualitative group interviews.
- Methods-triangulation provided the basis for deriving policy recommendations.

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<sup>32</sup> There are numerous publications that deal with the application of quantitative and/or qualitative methods of data collection (Bryman, 1988; Tesch, 1990; Dey, 1993; Miles & Huberman, 1994; Coffey & Atkinson, 1996; Easterby-Smith, Thorpe & Lowe, 2002; Zikmund, 2002; Collis & Hussey, 2003; Saunders, Lewis & Thornhill, 2003).

The most striking challenges that were accompanied with the application of a mixed-method approach were resource issues. The author had to dedicate a vast amount of time and effort to the project. Particularly the exploratory case studies were extremely time-consuming and caused a huge amount of travel expenses. Furthermore, it was difficult to schedule busy individuals for one-to-one, respectively, group interviews. Due to the increased complexity which is inherent in a multi-method approach additional time had to be allotted. Particularly the analysis of the qualitative data and the subsequent transformation into a concise questionnaire design was a very demanding process.

A further more general challenge of triangulation results from the fact that qualitative and quantitative approaches have different philosophical roots (constructivism vs. positivism). Quantitative as well as qualitative ‘paradigm warriors’ (cf. Tashakkori & Teddlie, 1998) like Smith (1983) or Lincoln & Guba (1985) have emphasised the incompatibility of the different epistemological positions underlying these research approaches.

In contrast, qualitative and quantitative methods often have been used together in the same research project and in many cases such integration has resulted in illuminating insights about the investigated phenomena. Consequently, one can find a considerable amount of publications about the integration of qualitative and quantitative methods (e.g. Denzin, 1978; Fielding & Fielding, 1986; Bryman, 1988; Cresswell, 1994; Tashakkori & Teddlie, 1998), ranging from rather abstract and general methodological considerations to practical guidelines for mixing methods and models in one research design.

In these discussions several authors have argued against the incompatibility thesis with various arguments: For instance, it has been stated that qualitative and quantitative methods are not exclusively tied to a specific epistemological standpoint and that the epistemological positions, often connected to different methodological traditions, converge at several points.

Furthermore, qualitative and quantitative methods now have been used for many years in empirical research; both methodologies are accepted by funding bodies, have led to generally accepted research results and thus influenced policies (Tashakkori & Teddlie, 1998). Consequently, many researchers and a growing number of methodologists adopt a pragmatic perspective on ‘paradigm wars,’ which may be described as follows: “Take whatever seems adequate from each paradigm or methodology for your research questions and leave the rest.”

Therefore, in the underlying research process, which is oriented on Zikmund (2002), the following three methods were employed in order to gather primary data:

- case studies (qualitative),
- survey (quantitative), and
- group interviews (qualitative).

The main purpose of the **case study research** was to identify relevant variables, to get a better understanding of the research context, and to refine basic hypotheses (Yin, 1994). In combination with the insights gained from the literature review the findings of the case study research were crucial for the design of a questionnaire, which was needed for the subsequent **survey**. The gathered quantitative data of the survey were used to test the formulated hypotheses and to illustrate the relationships between the relevant variables (Dillman, 2000; Oppenheim, 2000). In order to validate and verify the concluded research results and to derive policy recommendations **group interviews** with practitioners finally were conducted (Wass & Wells, 1994).

At this juncture it has to be noted that empirical work on the organisational structure of firms is relatively limited. This is primarily due to the lack of detailed information on structures and the difficulty in finding measures that allow comparisons across firms. As a result, previous research relies on either detailed datasets of a single firm (e.g. Baker, Gibbs & Holmstrom, 1994) or less detailed data on a smaller sample of firms (e.g. Scott, O'Shaughnessy & Capelli, 1996).<sup>33</sup>

As mentioned in the literature review, there is only Reger's article that deals with the R&D resource allocation via internal markets. In his work he investigated suitable forms and mechanisms for the coordination of international R&D and innovation processes in multinational corporations. Thus, his work had potential for the present investigation and mainly influenced the applied methodological approach.

Reger (1999) pointed out that an exploratory study appeared to be most appropriate for his investigation. His exploratory study was conducted in four steps. Firstly, as a conceptual framework various mechanisms for coordinating R&D and innovation were systematised into four categories and the most important tasks for coordination were selected. This conceptual framework was based on an in-depth literature review. Secondly, a structured interview guideline was developed. On this basis a series of interviews were conducted. Thirdly, the results obtained from these interviews were compiled into a set of case studies. Finally, as a last step, the results of the survey were presented at three workshops to representatives from the partner companies. This approach illustrates that Reger 'purely' relied on qualitative data in his study.

Thus, Reger's methodological approach can be compared with the exploratory stage of the present investigation, in which also a conceptual framework was developed that served as a basis for the exploratory case studies (refer to section 3.2). In contrast to Reger, the present investigation additionally aimed at exploring basic relationships between the investigated variables from a quantitative perspective. Thus, in a second step, an international survey was conducted, in order to test

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<sup>33</sup> There are several early empirical papers on organisational structure using cross-sectional techniques (e.g. Pugh, Hickson, Macdonald, Turner, Turner & Lupton, 1968; and Child, 1973).

the formulated hypotheses and to make generalising statements concerning the topic ‘internal R&D markets’. Thereafter, in conformity with Reger, the results were presented to representatives and R&D experts, in order to validate the findings. Reger (1999 p.73) described this final stage as “*very helpful for the analysis*”.

On the basis of the advantages of a mixed-method approach described in this section, the methodological approach of this inquiry can be seen as being sophisticated.

The following sections discuss the methodological issues associated with:

- the case study research (section 3.5),
- the survey (section 3.6), and
- the group interviews (section 3.7).

### **3.5 Case study research**

#### **3.5.1 Definition and application of case studies**

Case study research is a qualitative research methodology (Yin, 1994; Marshall & Rossman, 1999; Collis & Hussey, 2003). Zikmund (2002 p.115) refers to the case study as “*an exploratory research technique that intensively investigates one or a few situations similar to the researcher’s problem situation.*” Beside exploratory case studies there still exist other forms, such as descriptive, illustrative, experimental or explanatory case studies (Scapens, 1990).

Yin (1994) identifies the following characteristics of case study research:

- The research aims not only to explore certain phenomena, but to understand them within a particular context.
- The research does not commence with a set of questions and notions about the limits within which the study will take place.
- The research uses multiple methods for collecting data which may be both qualitative and quantitative.

The ‘classical’ case study research must be differentiated from other quite similar or related methods. In contrast to an experiment, environmental factors are considered and matter, since it is suspected that there is a relationship between the investigated phenomenon and its environment (Gallier, 1990; Yin, 1994). Action Research can be seen as a subgroup of case studies and experiments. However, it is an independent research approach where the researcher is part of the investigation object (e.g. as a member of an investigated organisation). Based on his theory the researcher tries to bring about changes and investigates them in order to get practical and theoretical results (Gallier, 1990). In contrast to the Grounded Theory, case study research is based on theories, which has been developed before the

actual beginning of the data collection. This means that the cases refer to certain research questions, basic assumptions or relationships between variables (Yin, 1994). On the other hand Grounded Theory starts with the data collection and derives theories from the gathered data.

Case studies are often used when the research questions are concerned with the HOW and WHY, or when the researcher has less control about the investigation object, and if it is a matter of current or new and temporary phenomena (Yin, 1994). According to the purpose Yin (1994) distinguishes the following main types of case studies:

- descriptive case studies for describing certain phenomena,
- explanatory case studies for the explanation of certain phenomena or for the test of theories, and
- exploratory case studies for the exploration or theory building.

Concerning the topic ‘internal R&D markets,’ there are only few related theories and a deficient body of knowledge. That’s why exploratory case study research was the appropriate approach for this stage of the research. The case studies focused on two main aspects:

- HOW are scarce R&D resources allocated on different types of R&D projects?
- WHY are the resource allocation processes organised in this way?

Compared with other instruments the main advantage of conducting case studies is the possibility to investigate certain phenomena in a very detailed manner (Gallier, 1990). Moreover, the closeness to real practical problems supports the relevance of the research (Gassmann, 1999). For example, Eisenhardt (1989) argues that only the connection with the practical reality allows developing provable, relevant and valid theories. A further advantage of case study research is the high degree of flexibility within the research process. New insights can be easily included and do not force the researcher to start from the very beginning.

Disadvantages result particularly from the high expenditure of time, the dependency from the cooperation of companies, the possibly low accuracy and/or lack of objectivity and the missing statistical generalisation of the research results (Gassmann, 1999). The last point restricts the expressiveness of the case study research since it is only possible to make generalisations regarding theoretical statements, but not concerning a population (Yin, 1994). Furthermore, the use of extensive, empirical material can lead to unclear theoretical statements that obstruct the view of the most important aspects (Eisenhardt, 1989).

Thus, certain qualitative criteria, such as validity and reliability are needed to achieve valid and reliable results (Healey & Rawlinson, 1994; Easterby-Smith, Thorpe & Lowe, 2002). Concerning the validity, Yin (1994) distinguishes between construct validity, internal validity and external validity. Construct validity refers to the establishment of correct operational measures for the concepts being

studied. Internal validity (for explanatory or causal studies only and not for descriptive or exploratory studies) is concerned with the establishment of a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships. External validity is concerned with establishing the domain to which the findings of the study can be generalised. On the other hand the criterion reliability is concerned with demonstrating that the operations of a study, such as the data collection procedures, can be repeated, with the same results.

### 3.5.2 Design and implementation of case studies

The described case study research process was oriented on Yin (1994). This process consists of the following five stages:

- preparatory stage,
- case selection,
- data collection,
- data analysis, and
- documentation.

After it was clarified that exploratory case study research would be an appropriate instrument for the inquiry, the research design was developed in the so-called **preparatory stage**. Before the actual start of the case study research some preliminary investigations were conducted. Therefore, the topic-relevant literature was screened in order to get familiar with the context in which the research should take place. Based on the findings of this literature review a list of questions was gathered, which built the basis for the subsequent semi-structured in-depth interviews with R&D experts. Saunders, Lewis & Thornhill (2003) describe semi-structured in-depth interviews as an adequate instrument for conducting exploratory case studies, since they are useful to “*find out what is happening [and] to seek new insights*” (Robson, 2002 p.59).

Yin (1994) points out that a proper research design of the case studies is crucial for their success. Particularly important are the study’s questions, its purpose and the unit of investigation. As already mentioned, the conducted case studies focused on the following questions:

- HOW are scarce R&D resources allocated on different types of R&D projects?
- WHY are the resource allocation processes organised in this way?

Since the topic ‘internal R&D markets’ had a very exploratory character it was difficult to define clear study propositions. But the study was based on some fundamental hypotheses that were set out in section 1.3. The main purpose of this exploratory study was to get a picture of the topic-related issues and to clarify the

taxonomy before embarking on a questionnaire. The primary unit of analysis were technology-intensive companies. In particular it was focused on the organisation of the resource allocation processes within these companies and how these processes differ concerning different types of R&D projects.

The **case selection** was oriented on the research design described above. The case studies were conducted in a set of technology-intensive companies. These companies are major players in their markets, have high R&D expenditures and are highly interested in improving the efficiency of their resource allocation processes due to an increasing competitive pressure in a global world economy. The access to these companies was facilitated by the fact that the underlying research project was supported by the German Federal Ministry of Education and Research. Since the validity of the findings depends on the number of cases, multiple-cases were conducted (Yin, 1994). But, one has to consider that at a certain point the marginal utility of each further case study is decreasing. That's why the total number of cases was restricted to nine. As mentioned above, semi-structured in-depth interviews were selected as basic instrument for the conducted case study research.

The following criteria were implemented for choosing the experts for the one-to-one interviews:

- position of a chief technology officer or R&D manager,
- many years of working experience in the R&D field, and
- expertise about the organisation of R&D resource allocation processes and the R&D organisation in general.

Concerning the establishment of personal contact, it can be summarised that managers prefer to be interviewed rather than fill in a questionnaire (North, Leigh & Gough, 1983; Healey, 1991). The expertise of the selected practitioners was important at this stage of the research in order to identify the most relevant variables, to build a theory on internal R&D markets and to derive hypotheses. Furthermore, the experiences and perceptions of practitioners were crucial to focus the further research on the main aspects that were essential for the design of a questionnaire, which was needed in the subsequent survey stage (Dillman, 2000; Oppenheim, 2000). Thus, the expert interviews were selected as the main instrument of **data collection** within the case study research.

In order to conduct the set of case studies in a similar way and thus increasing reliability a case study protocol / interview guide was designed (see appendix 1). In addition to that other data such as annual reports, internal documents and presentations as well as published data from the companies' homepages were taken into consideration (data triangulation). The data collection was particularly focused on gathering data concerning the current state of the R&D resource allocation as well as about potential starting points for a market-driven allocation of scarce R&D resources. The output of the case study research was mainly qualitative (i.e. words) but to some extent quantitative data such as the R&D quota, sales

figures etc. were included in the analysis. The findings of the case study research were recorded by note-taking and the collected data were saved in a database (Saunders, Lewis & Thornhill, 2003).

The **data analysis** of the case studies took place in two stages. In a first stage a within-case analysis was conducted to get an in-depth understanding of each case. This also helped to simplify the extensive evaluation of the data by focusing on the main aspects of each case. In the second stage the won realisations were structured and compared within the scope of a cross-case analysis (Yin, 1994). The analysis was oriented on the fundamental hypotheses set out at the beginning of the study (see section 1.3) and the developed interview guide (see appendix 1).

Accordingly, the analysis focused on the following four aspects:

- Characteristics of R&D project types,
- R&D organisation,
- R&D resource allocation, and
- Allocation result.

In order to make improvements and to close existing data gaps within the course of the case study research the data analysis was already started during the data collection stage. This procedure helped to identify first relationships between certain variables and ensured an efficient implementation.

Finally, the research results of the case studies had to be documented. A first version of the case study results was sent to the responsible experts in the companies in order to validate and verify the documented findings. If necessary the documentation was re-drafted.

The **documentation** was structured according to the following four main aspects:

- Characteristics of R&D project types,
- R&D organisation,
- R&D resource allocation, and
- Allocation result.

The single case studies are shown in appendix 1 and the cross-case analysis is presented in chapter 4. As already mentioned, the findings of the case studies in conjunction with the insights gained from the literature review provided the basis for the international survey, which is described in the following section.

## 3.6 Survey

### 3.6.1 Research model

The underlying research model of the survey is based on the findings of the literature review (see chapter 2) and the exploratory case studies (see chapter 4 and appendix 1). According to the central research questions and the basic structure of the case studies the survey focused on the following aspects:

- Characteristics of R&D project types,
- R&D organisation,
- R&D resource allocation, and
- Allocation result.

Since the study aimed at exploring project type-specific differences concerning these aspects it was necessary to develop a project typology. Based on the insights from the literature review (see section 2.1) and the case studies (see section 4.2) the following three types of R&D projects were created:

- Type 1: Research & Technology projects<sup>34</sup>
- Type 2: Projects for the development of new products and processes<sup>35</sup>
- Type 3: Projects for the enhancement of existing products and processes<sup>36</sup>

In a first step, it was investigated if there are differences across R&D project types concerning the project characteristics. Moreover, it was analysed if there are differences across project types concerning the R&D organisation. Then it was investigated if there are project type-specific differences concerning the applied form of R&D resource allocation. Eventually, the project type-specific differences concerning the effectiveness and/or efficiency of market-driven forms of resource allocation were analysed.

In this context the following basic hypotheses were formulated:

H1: There are differences across R&D project types concerning the project characteristics.

H2: There are differences across R&D project types concerning the R&D organisation.

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<sup>34</sup> Objective is to gain insights (e.g. basic research, applied research, methodology research).

<sup>35</sup> Objective is the development of new marketable products/processes.

<sup>36</sup> Objective is the development of product enhancements (derivatives) and process enhancements, based on existing products and processes.

H3: There are differences across R&D project types concerning the application of market-driven forms of resource allocation.

H4: There are differences across R&D project types concerning the effectiveness and/or efficiency of market-driven forms of resource allocation.

Figure 15 illustrates the main relationships between the central aspects of the research model as well as the underlying basic hypotheses.

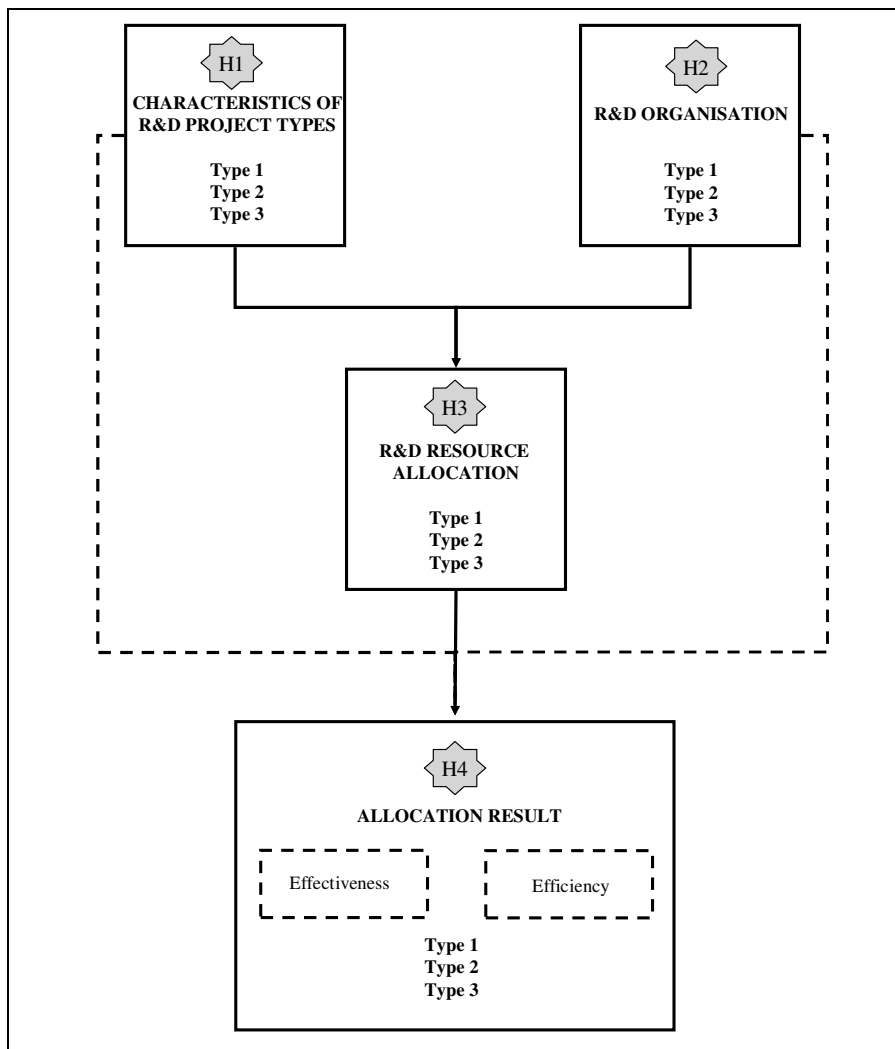


Figure 15: Research model

The basic hypotheses stated above were refined and specified according to the findings of the conducted case studies (see section 4.6) before they were tested within the scope of the survey. On the basis of the conducted hypothesis-testing conclusions were drawn regarding the applicability and favourability of internal R&D markets.

The tests of these hypotheses as well as the analysis and discussion of the survey findings are presented in chapter 5.

### **3.6.2 Research arrangements and instruments**

To test the hypotheses as well as the taxonomy, a questionnaire was designed (see appendix 2). Survey methodology appeared to be suitable in the unexplored field of internal R&D markets, because the questionnaire could be well structured, due to the extensive theoretical preparations (see chapter 2 and section 3.2) and the conducted case studies (see chapter 4 and appendix 1). The survey was conducted in form of a cross-sectional study. In contrast to longitudinal studies, where respondents are questioned at different moments in time, in cross-sectional studies the data were collected at a single point in time (Saunders, Lewis & Thornhill, 2003; Zikmund, 2002).

The main reason for choosing such approaches are feasibility aspects, since in many companies there is often only a limited willingness to cooperate in a business research project (Van de Ven & Poole, 1989; Van de Ven, 1992). The decision to participate in a survey often depends on the corresponding expenditure of time (Dillman, 2000; Oppenheim, 2000; Saunders, Lewis & Thornhill, 2003). Since longitudinal studies are much more time-consuming than cross-sectional studies, a higher willingness to cooperate could be expected by using this approach.

In this way various segments of the population were sampled so that relationships among variables could be investigated by applying statistical methods (see chapter 5). The collected data by means of the survey helped to evaluate the favourability of market-driven forms of R&D resource allocation and to derive policy recommendations for the design of an internal R&D market (see section 7.2).

This procedure was considered as being superior in comparison to statistical-based measures gained from secondary data analysis, such as financial results, market shares, speed of innovation etc., since they are fraught with problems when it comes to performance measurement in R&D.

Twiss (1994 p.49) describes these problems as follows:

“There will always be limited investment funds available and these must be divided between areas where they might be expected to give a quick return, such as advertising, and investments for the long term, such as R&D. But R&D is not alone in claiming funds which will not give an immediate return, although it is the most difficult to justify on a cost:benefit basis, for it is rarely possible to correlate R&D expenditure directly with a measurable change in profitability since the effects are usually obscured by other factors. A product may, for example, fail in the market-place through deficiencies in marketing or over-pricing, although technically it might have been a success. Conversely, good merchandising may largely counteract the deficiencies of a mediocre product. While it is difficult to isolate the R&D contribution to product profitability, it is even more difficult to correlate company profitability over a period covering such disturbances as tax changes and economic cycles, with earlier investment in R&D.”

In this setting a written postal survey was selected as the basic research method (Dillman, 2000; Oppenheim, 2000). This quantitative method offered some important advantages in the context of the present investigation (Easterby-Smith, Thorpe & Lowe, 2002; Zikmund, 2002; Collis & Hussey, 2003; Saunders, Lewis & Thornhill, 2003): Since it was intended to conduct a worldwide study a mail survey was an appropriate instrument because it provided a high geographical flexibility at low cost. Furthermore, the anonymity of the respondent was high and the respondent could answer the questions at his own convenience and had time to reflect on answers. Due to the nature of a mail survey there was no interviewer bias, which is a further argument for the application of this method.

On the other hand there are also several disadvantages to be aware of: For example, the speed of data collection was rather slow and there was no direct control over the return of questionnaires, which was problematic in terms of achieving a high response rate.<sup>37</sup>

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<sup>37</sup> Potential research participants who receive a questionnaire through the post may be reluctant to complete it for several reasons (Healey, 1991; Saunders, Lewis & Thornhill, 2003): They may feel that it is not appropriate to provide sensitive and confidential information to someone they have never met. They may also not completely trust the way in which the information provided is to be used. Furthermore, they may be reluctant to spend time providing written explanatory answers, where these are requested, especially if the meaning of any question is not entirely clear.

Given the research topic there was another factor that made it difficult to receive a huge number of responses. It was the fact that the research topic dealt with the organisation of R&D activities. To gather data in this sensible field is generally difficult because of nondisclosure aspects (Healey, 1991). Many companies are not willing to participate in any form of research (interviews, cases studies, surveys etc.) in this area.

In order to achieve as many responses as possible and to avoid respondent misunderstanding the design of the questionnaire had main emphasis. The validity and reliability of the collected data as well as the response rate depended, to a large extent, on the design and structure of the questionnaire, and the rigour of pilot testing (Saunders, Lewis & Thornhill, 2003). Valid questions enable accurate data to be collected, whereas questions that are reliable mean that these data are collected consistently. In this context Foddy (1994, p.17) emphasises that *“the question must be understood by the respondent in the way intended by the researcher and the answer given by the respondent must be understood by the researcher in the way intended by the respondent.”*

To refine the taxonomy, which was needed for the questionnaire design, an extensive literature review was conducted (see chapter 2). In this context the topic-relevant theoretical concepts, such as the principal agent theory, the transaction cost theory, the property rights theory etc., were scrutinised concerning their contribution to the research topic (see section 2.4).

In total the questionnaire comprised 41 questions. Since almost every question distinguished three different R&D project types, actually about 120 questions had to be answered. The questions of the designed questionnaire were highly standardised and were formulated as fixed-alternative questions. In contrast to open-ended response questions that are most beneficial when exploratory research is being conducted, fixed-alternative questions are questions in which the respondent is given specific limited-alternative responses and is asked to choose the one closest to his or her own viewpoint (Dillman, 2000; Zikmund, 2002; Saunders, Lewis & Thornhill, 2003).

If possible, a five-point ordinal Likert scale was applied. *“With the Likert scale, respondents indicate their attitudes by checking how strongly they agree or disagree with carefully constructed statements that range from very positive to very negative toward the attitudinal object.”* (Zikmund, 2002 p.312). This procedure is an extremely popular established standard in business research since the Likert scale method is simple to administer (Likert, 1932). By applying this scaling method the comparability of the raised data was increased.

In order to avoid potential problems that may be caused by the questionnaire a pre-test was conducted before the questionnaires were actually sent to the sampled companies (Zikmund, 2002). *“The purpose of the pilot test is to refine the questionnaire so that respondents will have no problems in answering the questions and there will be no problems in recoding the data. In addition, it will enable you to obtain some assessment of the questions’ validity and the likely reliability of the data that will be collected.”* (Saunders, Lewis & Thornhill, 2003 p.308).

The questionnaire was designed according to the findings of the previous investigations and was structured as follows:

- Characteristics of R&D project types,
- R&D organisation,
- R&D resource allocation,
- Allocation result, and
- Supplementary questions (general data concerning the company and the respondent were raised).

The questionnaire itself is shown in appendix 2. The raised data were entered in a database and then were analysed by using statistical software tools (SPSS/Statistica; refer to Shannon, 2000; Bühl & Zöfel, 2002; StatSoft, Inc., 2004).

### **3.6.3 Investigation objects**

#### ***3.6.3.1 Population and sampling procedure***

In the following the population and the corresponding sampling procedure are discussed.

The sampling process can be subdivided into seven different stages (Zikmund, 2002 p.372):

- define the target population,
- select a sampling frame,
- determine if a probability or non-probability sampling method will be chosen,
- plan procedure for selecting sampling units,
- determine sample size,
- select actual sampling units, and
- conduct fieldwork.

The preliminary investigations made clear that the concept of an internal R&D market is particularly valuable and only affordable for huge technology-intensive groups with internationally dispersed R&D activities. Thus, the target population of the survey were huge multinational groups that are active in R&D-intensive industries.

The main selection criteria were:

- the size of the company (compared with market capitalisation), and
- the R&D-intensity (compared with the R&D quota).

This implies that the sampled companies are major players in their markets, have high R&D expenditures and thus should be highly interested in improving the efficiency of their resource allocation processes.

Within the scope of the sampling procedure for the survey the 'Fortune Global 500 Database' served as the basic sampling frame. This database comprises the 500 largest companies worldwide (compared with market capitalisation) and provides key financial and company contact information.

With regard to a study of NIW et al. (1996), companies with an R&D quota of more than 3.5% (R&D expenses in relation to turnover) can be considered as high technology companies. Thus, the study focused on companies of the following R&D-intensive industries:

- Automotive,
- Chemicals,
- Electronics,
- Pharmaceuticals, and
- Telecommunications.

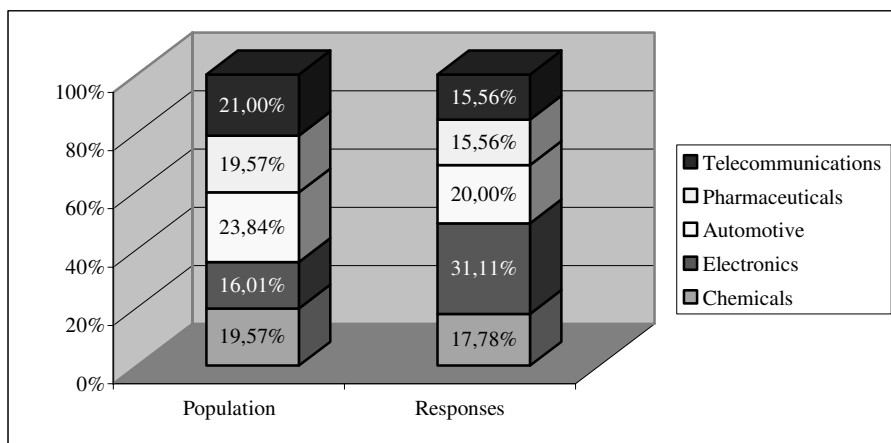
The selection criteria mentioned above led to a total population of 281 companies. Given this relatively small population the application of a certain probability or non-probability sampling method was not necessary (Schnell, Hill & Esser, 1992 p.282). Rather every possible case, respectively, every company could be investigated. This type of sample selection is termed a census (Saunders, Lewis & Thornhill, 2003 p.150). A census can be considered as a special form of a probability sample, in which all elements of the population are "*coincidentally chosen with a probability of 1.*" (Schnell, Hill & Esser, 1992 p.282).

The questionnaires were sent to the responsible Chief Technology Officers or R&D managers. They served as key informants because they are responsible for the creation and implementation of innovations. Thus, they should be also responsible for innovative organisational concepts, such as internal R&D markets.

### 3.6.3.2 Response rate and representative aspects

The dispatch of the questionnaires and the corresponding covering letters<sup>38</sup> took place in the second half of the year 2002. They were sent to the responsible R&D managers, respectively, to the Chief Technology Officers (CTOs). In this way it was tried to reach so-called ‘key informants’ (Kubicek, Wollnik & Kieser, 1981) that are interested in and have knowledge about the R&D resource allocation. These key informants were expected to provide valuable information concerning the project type-specific organisation of R&D resource allocation.

In order to encourage the sampled companies, respectively, R&D experts to participate in the survey it was offered to provide a free summary of findings after the end of the study. Three to four weeks after the dispatch of the questionnaires friendly reminders were sent to the non-responding companies in order to increase the number of responses (deVaus, 2002; Saunders, Lewis & Thornhill, 2003). In total 45 companies participated in the survey. Compared with the population of 281 companies this meant a response-rate of 16.01%. Figure 16 shows the frequency distribution of the initial population and the participating companies by industry.



**Figure 16: Frequency distribution of population and responses**

<sup>38</sup> “Most self-administered questionnaires are accompanied by a covering letter, which explains the purpose of the survey. This is the first part of the questionnaire that a respondent should look at. Unfortunately some of your sample will ignore it, while other use it to decide whether to answer the accompanying questionnaire.” (Saunders, Lewis & Thornhill, 2003 p.305).

Since the statistical significance of relationships is determined partly by the sample size it can be argued that it is very difficult to obtain a significant test statistic with a rather small sample. In this context Saunders, Lewis & Thornhill (2003 p.357) make the following statement: “*Conversely, because the impact of sample size declines rapidly for samples over about 30 cases, if you have an extremely large sample it is relatively easy to obtain a significant test statistic for a relationship that is in reality not that obvious!*”

Despite the partially high response-rate within some industries – e.g. Electronics – there is a danger that the non-responding companies differ systematically from the responding companies, which reduces the possibility to establish representative findings (Schnell, Hill & Esser, 1992).

According to NIW et al. (1996) companies can be subdivided into the following three categories with regard to their technology-intensity (see Table 3).

Category	R&D quota
I	<3.5%
II	3.5% - 8.5%
III	>8.5%

**Table 3: Definition of technology-intensity**

As mentioned above, the selection criteria for the definition of the population were:

- the size of the company (compared with market capitalisation), and
- the R&D-intensity (compared with the R&D quota).

Within the scope of the survey it was thus focused on the Global 500-industries that have an average R&D quota of more than 3.5%, i.e. the categories II and III. The conducted survey produced the following frequency distribution concerning the R&D quota (see Table 4).

R&D quota	Companies (absolute)	Companies (in percent)
<3.5%	10	22.22%
3.5% - 8.5%	24	53.33%
>8.5%	11	24.44%
<b>Total</b>	<b>45</b>	<b>100%</b>

**Table 4: Technology-intensity of the participating companies**

### 3.6.3.3 *Presentation of findings and statistical procedure*

The actual process of analysis was performed on the basis of the raised data.

This process comprised several interrelated stages (Zikmund, 2002):

- from editing and coding of the data,
- via data processing,
- to the application of different analysis methods for hypothesis-testing, and
- finally the interpretation of findings.

Before the data could be coded some editing was necessary. This means that the data were checked and adjusted for omissions, legibility, and consistency. Coding, on the other hand, means the process of identifying and classifying each answer with a numerical score or other character symbol. The coding process permitted the transfer of data from the survey to the computer, as well as the processing of the data in the computer. Before the actual analysis process could start the data were entered into a data matrix, which arranged the data into rows and columns. For the evaluation of the data statistical software-tools were used (SPSS/Statistica; refer to Shannon, 2000; Bühl & Zöfel, 2002; StatSoft, Inc., 2004).

In general, the following analysis methods can be distinguished (Zikmund, 2002):

- descriptive analysis,
- univariate analysis,
- bivariate analysis, and
- multivariate analysis.

Since the character of the research topic 'internal R&D markets' was rather exploratory, the main purpose of the data analysis was to demonstrate fundamental relationships between the variables of the research model; for example, between the project types and the applied form of resource allocation.

Thus, descriptive analysis methods were applied in order to transform the raw data into a form that made them easy to understand and interpret. The data were summarised by calculating median, range, frequency distributions, and percentage distributions (Zikmund, 2002). In this context the data were scanned for outliers with the help of graphical methods (Sparrow, 1989); but no abnormalities were found. The statistical analyses undertaken and presented in this thesis were standard procedures, i.e. cross-tabulations.

The main purpose of the cross-tabulations (bivariate analysis) was to get a better overview of the raised data. It allowed the inspection of differences among the project types and to make comparisons, as well as it helped to determine the form of association between the variables (Zikmund, 2002).

To test the significance of the findings chi-squared-testing was applied. Collis & Hussey (2003 p.241) define a chi-squared test as “*a non-parametric technique which is used to assess the statistical significance of a finding, by testing for contingency (uncertainty of occurrence) or goodness of fit.*” The test involves setting up (1) a null hypothesis that states that two variables are independent of one another and (2) an alternative hypothesis, which states that they are associated with one another. “*Proper use of the chi-square test requires that each expected cell frequency ( $E_{ij}$ ) have a value of at least 5. If this sample size is not met, the researcher should take a larger sample or combine (“collapse”) response categories.*” (Zikmund, 2002 p.524).

Due to the relatively small number of responses it appeared useful to combine the response categories, so that the conducted chi-square tests were calculated on the basis of an aggregated categorical scale with three response categories. Based on chi-squared-testing it was investigated whether there were any statistically significant differences between the actual (observed) frequencies and hypothesised (expected) frequencies. In this way it was shown, whether the differences between the investigated R&D project types were due to some underlying, universal difference or merely to chance (Collis & Hussey, 2003).

If the probability of the test statistic having occurred by chance alone was very low ( $p=0.05$  or lower), then a statistically significant relationship existed. If  $p>0.05$ , then it was concluded that there exists no statistically significant relationship. Nevertheless, there may still be a relationship between the variables, but a conclusion cannot be drawn with any certainty (Saunders, Lewis & Thornhill, 2003).

### **3.7 Group interviews**

The findings of the literature review (see chapter 2) and the case studies (see chapter 4 and appendix 1) in combination with the quantitative survey results (see chapter 5) provided the basis for deriving policy recommendations on how to design an internal R&D market.

In order to validate and verify the empirical findings and to formulate concrete policy recommendations for the design of an internal R&D market a set of group interviews was conducted. These interviews with experts from the partner companies helped to clarify the content of some of the empirical results and to get at the meaning behind some of the data (Wass & Wells, 1994; Saunders, Lewis & Thornhill, 2003).

Group interviews generate qualitative data (Collis & Hussey, 2003) and are usually relatively unstructured and fairly free-flowing (Zikmund, 2002). Since the group interviews mainly aimed at validating and verifying the findings of the survey they were conducted as semi-structured interviews (Wass & Wells, 1994). The structure was oriented on the empirical findings of the study.

Zikmund (2002) states that the primary advantages of group interviews are that *“they are relatively brief, easy to execute, quickly analyzed, and inexpensive.”* (Zikmund, 2002 p.117). But, compared with one-to-one interviews the opportunity to develop an individual rapport with each participant will not be present (Saunders, Lewis & Thornhill, 2003).

Moreover, the use of group interviews *“is likely to necessitate a balance between encouraging participants to discuss the particular question or questions that you introduce and allowing them to range more freely in their discussion where this may reveal data that provide you with important insights.”* (Saunders, Lewis & Thornhill, 2003 p.270).

This method also allows the participants to discuss points between themselves and to challenge one another's views. In contrast to one-to-one interviews, group interviews provide the opportunity to efficiently interview a larger number of experts. Typically, a focus group will consist of four to eight participants (Saunders, Lewis & Thornhill, 2003).

In the context of the present investigation the following procedure was employed for forming an adequate focus group (Saunders, Lewis & Thornhill, 2003):

In a first step, a group of experts, which have sufficient experience concerning R&D resource allocation processes, was invited. In total three group interviews with different experts from the partner companies were conducted.

The implementation of the group interviews took place in the first half of the year 2003. The groups consisted of four to six R&D experts. These experts had different functions and backgrounds (head of R&D, head of division, R&D manager etc.) and thus they evaluated the research findings from different perspectives, which facilitated the discussion and thus provided a rich set of data.

In the session itself it was important to introduce the group members and to discuss the purpose of the study as well as what will happen in the group interview. It was explained that the group interviews mainly aimed at validating and verifying the findings from the quantitative survey and at deriving policy recommendations.

To facilitate the discussion, visual examples of the most interesting empirical results were displayed by using an overhead projector. All the group members were allowed to discuss the topics among themselves and it was ensured that all participants had an opportunity to contribute. This was important since a specific shortcoming of group interviews is that a single, self-appointed participant may dominate the session (Zikmund, 2002).

A list of prepared topics was used in order to ensure that all topics were covered. Main emphasis had the discussion of the findings concerning the characteristics of R&D project types, the R&D organisation, the R&D resource allocation, and the allocation result. The group discussions helped to get at the meaning of some of the research findings and thus helped to derive policy recommendations. Specifically, the group interviews made the following essential contributions:

- First of all they helped to select the most appropriate characteristics for the categorisation of different types of R&D projects. Moreover, they confirmed that certain project characteristics in combination with certain organisational arrangements enable market-driven forms of resource allocation. Since the conducted studies showed that there are practical differences concerning the company-specific project typologies, the R&D experts proposed the creation of a universally applicable model for the evaluation of the applicability of internal R&D markets. Therefore, based on the project characteristics and the organisational arrangements, a model was developed that helps to decide whether a certain R&D project can be traded via an internal R&D market, without taking into account the respective project type.
- Moreover, the interviewed experts pointed out that potential reorganisation efforts towards a more market-driven allocation of R&D resources must be based on the actual state concerning the prevailing structures and processes. On this basis, so their suggestion, one or several alternative allocation designs can be developed. In this context they validated the elements of internal R&D markets, as they were discussed in the conceptual framework in section 3.2. These features give the potential 'designer' (e.g. management board) of an internal R&D market a clue which elements can be designed, in principle. However, the experts remarked that the decision-makers have to bear in mind that for each element numerous designs are basically conceivable and that there is no single standardised solution. In this way the group interviews helped to determine a set of elements for the design of internal R&D markets.
- The group discussions were also helpful for the development of a model for the evaluation of the favourability of internal R&D markets. In this context the interviewees stated that in addition to the criteria effectiveness and efficiency also secondary effects must be taken into consideration when deciding upon alternative forms of resource allocation. Furthermore, they preferred a mix of qualitative and quantitative methods (i.e. scoring approach in combination with the net present value approach) for the evaluation of the favourability of alternative forms of resource allocation. This provided the basis for the development of a mutually accepted evaluation model.

In summary, the dynamic group discussions generated a lot of valuable ideas (e.g. use of the Intranet as a platform for internal R&D markets). Moreover, they helped to develop recommendations for the establishment and design of internal R&D markets. The major findings of the group interviews are presented in chapter 6 and the derived policy recommendations are shown in section 7.2.

### 3.8 Ethical considerations and delimitations

Research ethics play an increasingly important role, especially in business research. Thus, this section deals with ethical aspects and delimitations relevant to the present investigation. Saunders, Lewis & Thornhill (2003, p.129) point out that “*ethics refers to the appropriateness of your behaviour in relation to the rights of those who become the subject of your work, or are affected by it*”. General business ethics should be a standard for business researchers. Ethical issues that generally affect the research process are (Saunders, Lewis & Thornhill, 2003 p.131):

- privacy of possible and actual participants,
- voluntary nature of participation and the right to withdraw partially or completely from the process,
- consent and possible deception of participants,
- maintenance of the confidentiality of data provided by individuals or identifiable participants and their anonymity,
- reactions of participants to the way in which you seek to collect data,
- effects on participants of the way in which you use, analyse and report your data, and
- behaviour and objectivity of the researcher.

However, in business research there is no written code and it is up to the researcher and his supervisors to determine what is ethical (Collis & Hussey, 2003). Nevertheless, the code of ethics for the American Association for Public Opinion Research could serve as an example for several major ethical issues that have to be considered in business research.<sup>39</sup> Moreover, Saunders, Lewis & Thornhill (2003) provide a list with a number of useful codes of ethics that are published on the Internet.

Regarding these examples, the author had to maintain high standards to ensure that all data that were collected during the research were accurate. Further, the author must not intentionally try to prove a particular point for political purposes. Since the research was mainly concerned with the efficient organisation of R&D resource allocation processes confidentiality was identified as being the major ethical issue within the scope of the thesis. Not only concerning the raised data but also concerning the R&D activities themselves.

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<sup>39</sup> Several principles and standards are expressed in this code: I. Principles of Professional Practice in the Conduct of Research, II. Principles of Professional Responsibility in Dealings with People, III. Standards for Minimal Disclosure. (Zikmund, 2002 pp.82-83).

Regarding the data collection stage, the following ethical issues were considered: All parties involved in the case study research and the subsequent survey were informed about the nature and aims of the project. Moreover, they were informed that they are free to withdraw from the study at any time. In this context Zikmund (2002 p.79) makes the following statement: "*The notion of informed consent means that an individual understands the reason for the research and waives his or her right to privacy when he or she agrees to participate in the research study.*" Thus, it was the responsibility of the author to ensure that the privacy and anonymity of the participants were preserved.

Concerning the conducted interviews, there were also some specific ethical issues that must be considered. Saunders, Lewis & Thornhill (2003) mention that the interview situation will place the researcher in a powerful position, because he will be able to formulate questions, including probing ones, which may cause levels of discomfort. Additionally, the researcher should consider that he will need to remain sensitive to the fact that his presence is a temporary one, whereas the people from whom he will collect the data will need to work together after his depart. Concerning the research topic, the author had to be very sensitive when conducting the interviews, especially concerning secrecy and nondisclosure aspects that are of major importance in the R&D field.

Moreover, the gathered data of the survey were treated with the strictest confidentiality. The results were published in aggregated form only, ensuring that no inference can be drawn on participating companies. Furthermore, the author discussed and verified the research results together with the participating parties of the case studies in order to present correct results.

Eventually, it was important to share the new knowledge and findings of the research by publishing the research results (see Völker & Kasper, 2002; Völker & Kasper, 2004). Concerning this, the author had to give credit to anyone whose ideas made a significant contribution to the research.

Finally, the author had to ensure that all the relevant data concerning the R&D resource allocation were protected and stored in an appropriate manner (Saunders, Lewis & Thornhill, 2003). This meant that the data must be adequate, processed fairly and lawfully, kept securely and if necessary, kept up to date.

In summary it may be said that the author had to adhere to the purpose of the research, maintain objectivity, avoid misrepresenting research findings, protect the right to confidentiality of all parties involved and avoid shading research conclusions.

With regard to the delimitations of this work, it has to be noted that the underlying research project was funded by the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung – BMBF). This organisation required periodic reports and records of expenditure.

The German Federal Ministry of Education and Research, however, agreed that it had no right to influence the design of the project beyond approving the initial idea and budget. Nor had the Ministry any rights to the research results. These general aspects were regulated in the project-related notification of the Ministry.

In total the Ministry gave financial support for one full-time equivalent. This meant that the author was the responsible project manager and that he had to conduct the project-related empirical studies as well as the related administrative work independently.

The research project for the German Federal Ministry of Education and Research was a largely empirical project and provided the basis for the thesis in hand. However, there were some differences between the scope of the Ministry project and the scope of the thesis, as outlined now.

The Ministry was mainly interested in:

- concrete project results and practical recommendations on how to deploy an internal R&D market,
- direct benefits for the companies, e.g. a more efficient use of R&D resources, cost cuttings, or the improvement of the innovation capabilities,
- the transfer possibility of the project results, e.g. the establishment of further internal markets in other corporate functions, and
- the meaning of the project results for the labour market.

Within the scope of the Ministry project qualitative data (i.e. case study research) and quantitative data (i.e. survey research) were gathered, which provided the basis for the thesis. In contrast to the research project of the German Federal Ministry of Education and Research, the thesis more strongly focused on:

- the derivation and discussion of the research problem,
- the formulation of research objectives,
- the discussion of methodological issues,
- the theoretical foundation of the research topic, e.g. extensive literature review concerning the state of the art of R&D resource allocation, or the discussion of basic theoretical concepts, such as the principal agent theory, the transaction cost theory, and the property rights theory and the analysis of their contribution to the research topic,
- the derivation of hypotheses and hypothesis-testing,
- the discussion and justification of the research results,
- the formulation of policy recommendations, and
- the identification of further research questions.

### 3.9 Methodological limitations

In this chapter the underlying methodological approach of the present inquiry was explained. It was pointed out that a mixed-method approach appeared to be of advantage. In the underlying research process the following three techniques were employed in order to gather topic-relevant primary data:

- case study research (qualitative),
- survey (quantitative), and
- group interviews (qualitative).

Each of these research methods, however, is subject to methodological limitations, but these limitations are often avoidable. In the following the main inquiry-related methodological limitations and their implications for the research findings are discussed.

With regard to the qualitative techniques (case studies and group interviews), there were several limitations to be aware of. First of all the conducted qualitative research consisted of relatively small samples that may not be representative of the entire population. Moreover, the research was strongly dependent on the cooperation of the interview partners. Without their accurate and complete answers the entire research project wouldn't have been possible.

Concerning the analysis of qualitative data the author is aware of the existence of several types of Computer-Assisted Qualitative Data Analysis Software (CAQDAS). Within published literature (Kelle, 1995; Miles & Weitzman, 1995; Coffey & Atkinson, 1996; Fielding & Lee, 1998; Fielding & Lee, 2002; Mangabeira, Lee & Fielding, 2004; Maylor & Blackmon, 2005) the most frequently mentioned and the most widely used CAQDAS appear to be all code-based theory builders, such as:

- ATLAS(TM),<sup>40</sup>
- NUD.IST,<sup>41</sup>

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<sup>40</sup> In addition to facilitating the code and retrieve process, ATLAS(TM) is capable of exploring data within semantic networks. Other advanced features are also available. Unique to ATLAS(TM) are the various ways of visualising and linking the various objects and elements of a project.

<sup>41</sup> One feature that is very particular to NUD.IST is the display of the coding scheme or index system in the form of a hierarchical tree structure. The NUD.IST tree is upside-down, with its root at the top. It is possible to freely manipulate the tree, thus the tree nodes and the segments coded at those nodes can be moved. Search results can be added under a new node and become part of the tree. The capability to search text and to write memos and annotations are also integral parts of the programme.

- Folio Views,<sup>42</sup> and
- HyperRESEARCH<sup>43</sup>.

Much has been written about the use of computers in qualitative data analysis. Proponents of CAQDAS argue that it serves to facilitate an accurate and transparent data analysis process whilst also providing a quick and simple way of counting who said what and when, which in turn, provides a reliable, general picture of the data (Richards & Richards, 1994; Morison & Moir, 1998). However, some commentators are expressing concern that the software may “guide” researchers in a particular direction (Seidel, 1991). Others have commented that using CAQDAS could serve to distance the researcher from the data, encourage quantitative analysis of qualitative data, and create a homogeneity in methods across the social sciences (Hinchliffe, Crang, Reimer & Hudson, 1997; Barry, 1998).

According to the above-cited literature the following advantages and disadvantages of using software packages for the analysis of qualitative data can be summarised:

#### Advantages

- Speed
- Greater flexibility
- More complex analysis processes become feasible
- The software offers new possibilities for analysing qualitative data.
- With the support of software, data can be analysed more systematically and according to specific criteria.
- Computers make it easy to handle large amounts of data
- The use of computers increases the status and plausibility of a qualitative research project

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<sup>42</sup> Programmes such as Folio Views are specifically designed to find words and strings of text in your data. They can do that much faster than word processors since their internal structure is different. In addition, they offer a number of complex search functions and operators. For example, it is possible to mark and sort data as well as to attach memos and comments. Some of these programmes support detailed content analysis, offer keyword-in-context display, word lists and counting functions. What they do not support is the coding of user defined text passages.

<sup>43</sup> Code-and-Retrieve functions are at the heart of rule-based-systems as HyperRESEARCH with a focus on deductive and case-oriented analysis. The analysis process is based on the formulation of rules. These rules are subjected to tests and are then either verified or falsified by the data.

### Disadvantages

- There is the danger of losing touch with the data
- You can perform a quick but dirty analysis
- Not everything can be put into a machine-readable form
- The positive effect of gaining more manageability can become lost due to high degrees of complexity
- The purpose of using the software can be misunderstood and lead to dull and meaningless analysis results

Weighing up the mentioned advantages and disadvantages the author came to the conclusion that the use of such software packages would not be beneficial to this work. Moreover, the reader can be confident that what was done was done with particular care.

Nevertheless, in some cases also problems occurred due to aspects of nondisclosure, which are of particular importance within R&D contexts. Moreover, in some interviews the lack of knowledge of the interviewees concerning the topic 'internal R&D markets' made some difficulties. In these cases the developed conceptual framework (see section 3.2) was helpful to ensure a uniform understanding of the term 'internal R&D market' and to generate valid and reliable interview data.

Although validity and reliability of qualitative research is discussed by many researchers (for example, Cook & Campbell, 1979; Silverman, 1983; Kirk & Miller, 1986), the most often quoted concept of the problem of establishing validity is probably the notion of trustworthiness that was developed mainly by Lincoln & Guba (1985). The aim of trustworthiness in a qualitative inquiry is to support the argument that the inquiry's findings are "*worth paying attention to*" (Lincoln & Guba, 1985 p.290).

The notion of trustworthiness has four elements:

- credibility,
- transferability,
- dependability, and
- confirmability.

Credibility is analogous to 'internal validity' in quantitative studies. It relates to how the reconstruction of the researchers fits the realities and views the participants express in the process of the inquiry. To address credibility three techniques were employed.

First, the technique of triangulation was used which involves the use of multiple sources to enhance the rigour of the research (Lincoln & Guba, 1985). Second, the help of a competent Peer Debriefing was enlisted. Peer debriefing contributes to guarding against researcher bias (Lincoln & Guba, 1985). Third, the technique of member checking was used, which means going back to the source of the information and check both the data and the interpretation (Lincoln & Guba, 1985). Each interview partner reviewed a summary of the data analysis and interpretation. This helped to assess the intentionality of the interviewees and often provided additional volunteer information. Moreover, errors were corrected and the overall adequacy of the raised data was increased.

Transferability is the counterpart to 'external validity' in quantitative studies. It refers to the possibility that what was found in one context by a piece of qualitative research is applicable to another context. This shows that the purpose of qualitative studies is not to make generalisations, but to explore the variation between and within the different cases (Lincoln & Guba, 1985).

To address transferability, the technique of purposive sampling was employed. In contrast to random sampling that is usually done in quantitative studies, this naturalistic non-random approach focuses on such cases that will quickly maximise the researcher's understanding of the research context. Data are collected and interpreted as the sampling evolves. The advantage of such samples is their speed and flexibility. The disadvantage is that they are not representative of the wider population (Saunders, Lewis & Thornhill, 2003).

To get a sufficiently varying foundation for the study, the case studies, respectively, the interviews were conducted in different technology-intensive industries, i.e. automotive, chemicals, electronics, pharmaceuticals and telecommunications. To further improve transferability, a within-case analysis and a cross-case analysis were conducted (Yin, 1994). The complete set of data analysis is documented and saved to disc. But, not all of the data are publicly available for confidentiality reasons. Nevertheless, the access to the analyses in this thesis gives other researchers the ability to transfer the conclusions of this inquiry to other cases, or to repeat, as closely as possible the procedures of this project. This technique is also known as thick description (Lincoln & Guba, 1985).

Dependability is the qualitative researcher's equivalent of the conventional term 'reliability' (Robson, 2002), which is equal to replicability. In quantitative research, reliability means that the same tests should produce the same results. For qualitative researchers, this kind of replicability is impossible to realise because the research design is so flexible and the research findings are produced by constantly changing interactions between researchers and participants. Thus, dependability focuses on the assessment of the quality of the integrated processes of data collection, data analysis, and theory generation.

On the other hand, confirmability is parallel to ‘objectivity’ in conventional criteria. It is a measure of how well the inquiry’s findings are supported by the data collected. Put differently, is the study designed to show what it is intended to show? In this context Schwandt (1997 p.164) points out that researchers need to link “*assertions, findings, and interpretations, and so on to the data themselves in readily discernible ways.*”

To address the issues of dependability and confirmability the author relied on an independent audit of the applied research methods by a competent peer (Lincoln & Guba, 1985).

In addition to the methodological limitations mentioned above there were also some methodological issues associated with the quantitative approaches that needed to be considered. Since the survey was an integral part of the underlying research project, which was supported by the German Federal Ministry of Education and Research, a German version of the questionnaire was developed at first. Given the target population of the survey, there was also a need to translate the German version of the questionnaire into English. However, obtaining high-quality data from respondents where German is not the home language requires more than just having a correctly translated data collection instrument. Recent research indicates that some correctly translated questions still pose conceptual problems and other difficulties for respondents (Carrasco, 2003).

Thus, an important task in the development of a questionnaire in multiple languages is the actual conduct of the translation. Or rather, taking words and their meaning in the source language and identifying words in a target language that convey the same or similar meaning. This task can be performed using a variety of approaches or techniques. Translation techniques discussed in the context of questionnaire translation talked about in the research literature include simple direct translation, modified direct translation, back-translation, and the committee approach (see Behling & Law, 2000; Harkness et al., 2003).<sup>44</sup> A recent review of statistically representative surveys in the U.S. showed that most survey translations rely for the most part on the direct translation approach (McNally 2001).<sup>45</sup>

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<sup>44</sup> Behling and Law (2000, p.15), for example, state the following regarding the importance of equivalence in translated questionnaires: “Demonstrating that the translated questionnaire possesses the basic characteristics required of all measurement instruments is not enough. In addition, the researcher must show that it exhibits appropriate levels of semantic and conceptual equivalence relative to the source language measure and that it and the procedures through which it is administered minimize any problems created by lack of normative equivalence.”

<sup>45</sup> The advantages of this method are apparent: it is cheap and quick. The drawbacks are less evident but important. Comparison of this simple direct translation approach with other approaches indicate that simple direct translation of data collection instruments does not compare well in terms of key criteria for data quality. These criteria include the extent to which the translated data collection instrument is informative and accurate, and the degree of language transparency (McKay et al., 1996; Behling & Law, 2000).

A simple direct translation is conducted by a single bilingual individual who translates the questionnaire from the source language into the target language. This approach was also applied in the present inquiry with the help of a bilingual English native speaker. Given this, the author is confident of the adequacy of the translated questions, which was also underpinned by the results of the conducted pre-test. Therefore, it can be stated that the used questionnaires were of a quality such that it was possible to collect valid and reliable data; provided the respondents have done the right work to give the required information and further assumed that they were honest in their response.

Further methodological limitations associated with the quantitative survey research mainly result from the relatively small number of responses. All else being equal, the margin of error is higher for small-sample surveys, and therefore the results are less projectable for surveys with smaller samples (Zikmund, 2002).

From the fact that every possible case, respectively, every company from the population (N=281) was investigated, there resulted some relevant specific features. As already mentioned, this type of sample selection is termed a census (Saunders, Lewis & Thornhill, 2003). Precondition of inferential statistics, i.e. for the conclusion from the sample to the population, is the fact that a probability sample is needed. A census can be considered as a special form of a probability sample, in which all elements of the population are "*coincidentally chosen with a probability of 1.*" (Schnell, Hill & Esser, 1992 p.282).

In this context it should also be considered that errors can occur when making inferences from samples. These errors are known as Type I and Type II errors (Zikmund, 2002; Saunders, Lewis & Thornhill, 2003). For example, Type I errors occur when it is concluded that there is a relationship between variables when in reality there is none. Type II errors involve the opposite occurring, e.g. when it is concluded that there is no relationship between variables when in reality there is one. The term 'statistical significance' refers to the probability of making a Type I error (Saunders, Lewis & Thornhill, 2003).

With regard to the survey there were some further methodological limitations that need to be discussed. The presented results and conclusions of the quantitative study (see chapter 5) were solely based on descriptive and bivariate analyses. On the basis of the raised database, the statistical work mainly focused on producing chi-square outcomes for a series of cross-tabulations, in order to investigate project type-specific differences. Based on the resulting statistical figures the data were evaluated and interpreted.

A more sophisticated statistical approach (multivariate analysis) was not taken due to the following reasons:

- Given the fact that this inquiry was the first in the field of 'internal R&D markets' the conducted research mainly aimed at exploring basic relationships between the investigated variables (e.g. between the project types and the applied form of resource allocation).
- Moreover, the operation of a more sophisticated approach would have required 'objective' differences between the different R&D project types. Given the descriptive research findings, presented in chapter 5, it has to be noted that the developed project typology 'subjectively' made sense to the respondents. However, the differences concerning the investigated project characteristics were not in all cases significant for the different R&D project types.
- Some further restrictions resulted from the fact that the research was undertaken in the sensible R&D field, in which it is generally difficult to receive a high number of responses. Given a sample size of 45 companies the presented analysis was based on a total of 135 observations (45 companies x 3 R&D project types). As already mentioned, the margin of error is higher for small-sample surveys, and therefore the results are less projectable for surveys with smaller samples. Thus, it was not recommendable to undertake a multivariate analysis.
- Last but not least there was a further, more general, reason why the use of multivariate analysis didn't appear to be suitable. This was the fact that the thesis has to be seen from an 'Industrial Organisation' perspective rather than from an 'Industrial Economics' perspective. As illustrated in the literature review, the number of empirical publications on the organisational structure of firms is relatively limited. This is primarily due to the lack of detailed information on structures and the difficulty in finding measures that allow comparisons across firms. Thus, the empirical works in this field more strongly rely on qualitative approaches.

The decision to adopt a bivariate approach implied that it was not possible to control for 'ceteris paribus' conditions (refer to Studenmund, 2001). However, as outlined above, multivariate approaches were not considered as being very useful in the context of this inquiry.

Further limitations result from the fact that this investigation is the first one that is concerned with the topic 'internal R&D markets' and that there are only a limited number of related studies published in peer reviewed journals. Moreover, the studies were difficult to compare as different variables were covered, different methods of analysis were used and often very different industries were studied.

The methodological limitations of the applied qualitative and quantitative research methods described above in conjunction with the exploratory character of the study and the relatively small sample size also have some implications for the present investigation. On the one hand the reader has to be aware that the research results presented in this thesis are at best indicative. This means that the study describes some basic relationships that are fundamental for the establishment of internal R&D markets. On the other hand one has to bear in mind that the methodological limitations limit the credibility of the findings and restrict the population to which findings can be applied. For practitioners it is therefore important to take into account the prevailing circumstances in their companies when making decisions about a more market-driven allocation of R&D resources.

Despite the methodological limitations and the associated implications for the study, which were described in this section, the applied methods were most appropriate within the context of the present investigation. As illustrated in this chapter, a sequential triangulation of research methods was used throughout the inquiry, including:

- case study research (see chapter 4),
- survey research (see chapter 5), and
- group interviews (see chapter 6).

As demonstrated in the following chapters, the raised qualitative and quantitative data complement one another and support the fundamental hypotheses of this work. Thus, the author is confident that the resulting outcomes, respectively, the research findings presented in this thesis are sufficiently robust to allow answering the set up research questions. Given the presumed quality of this study, the subsequently presented research findings should provide a sound base for establishing internal R&D markets in practice as well as for conducting future research activities in this area.

## **4 Findings of the case studies (cross-case analysis)**

### **4.1 Introduction**

In the following sections the findings of the case studies are presented. The methodological issues associated with the case study research were discussed in section 3.5. During the case study research a set of semi-structured in-depth interviews was conducted in nine technology-intensive companies (ABB, Abbott Laboratories, BASF, BMW, DaimlerChrysler, Henkel, Hilti, Roche and Syngenta).

The analysis of the qualitative case study data took place in two major steps. Firstly, a within-case analysis was conducted, in which each case was analysed in-depth (see appendix 1). Secondly, a cross-case analysis was conducted, in which the different cases were compared. In this way differences and similarities were elaborated and testable hypotheses were derived.

The documentation of the cross-case analysis is structured as follows:

- Characteristics of R&D project types (section 4.2),
- R&D organisation (section 4.3),
- R&D resource allocation (section 4.4), and
- Allocation result (section 4.5).

Given the research questions and research objectives of the study, the investigation of project type-specific differences has main emphasis. In this way the following central hypotheses are refined and specified:

H1: There are differences across R&D project types concerning the project characteristics.

H2: There are differences across R&D project types concerning the R&D organisation.

H3: There are differences across R&D project types concerning the application of market-driven forms of resource allocation.

H4: There are differences across R&D project types concerning the effectiveness and/or efficiency of market-driven forms of resource allocation.

The main findings of the case study research as well as a statement of the derived hypotheses are finally summarised in section 4.6.

## 4.2 Characteristics of R&D project types

Within the scope of the exploratory studies, nine case studies in multinational, R&D-intensive groups were conducted. Despite the fact that the companies belong to different industries they use quite similar project typologies. Table 5 shows the project categories, which were found within the course of the case study research.

Company:	Project categories:
ABB	Fuzzy Front End projects
	Projects for the development of technology platforms
	Product development projects
	Contract development projects
Abbott Laboratories	Breakthrough-Innovation projects
	New Product Development projects
	Line Extensions
BASF	Research & Technology projects
	New product development projects
	Projects for the development of new and improved processes
	Projects for the enhancement of existing products
BMW	Research and preliminary development projects
	Serial development projects
	Variants
DaimlerChrysler	Research and preliminary development projects
	Development projects
	Contract development projects (Variants )
Henkel	Research projects (so-called basic development projects)
	Product development projects
	Technical services projects
Hilti	Research & Technology projects
	Product development projects
	Product enhancement projects
Roche	Research & Technology projects
	New product development projects
	Product enhancement projects
Syngenta	Research projects
	Product development projects
	Product enhancement projects

**Table 5: Categories of R&D project types**

According to the dimensions shown in the literature review (see section 2.1) the company-specific project categories could be classified into the following three main clusters (see Figure 17):

- Cluster 1: Research & Technology Projects
- Cluster 2: Projects for the Development of New Products and Processes
- Cluster 3: Projects for the Enhancement of Existing Products and Processes

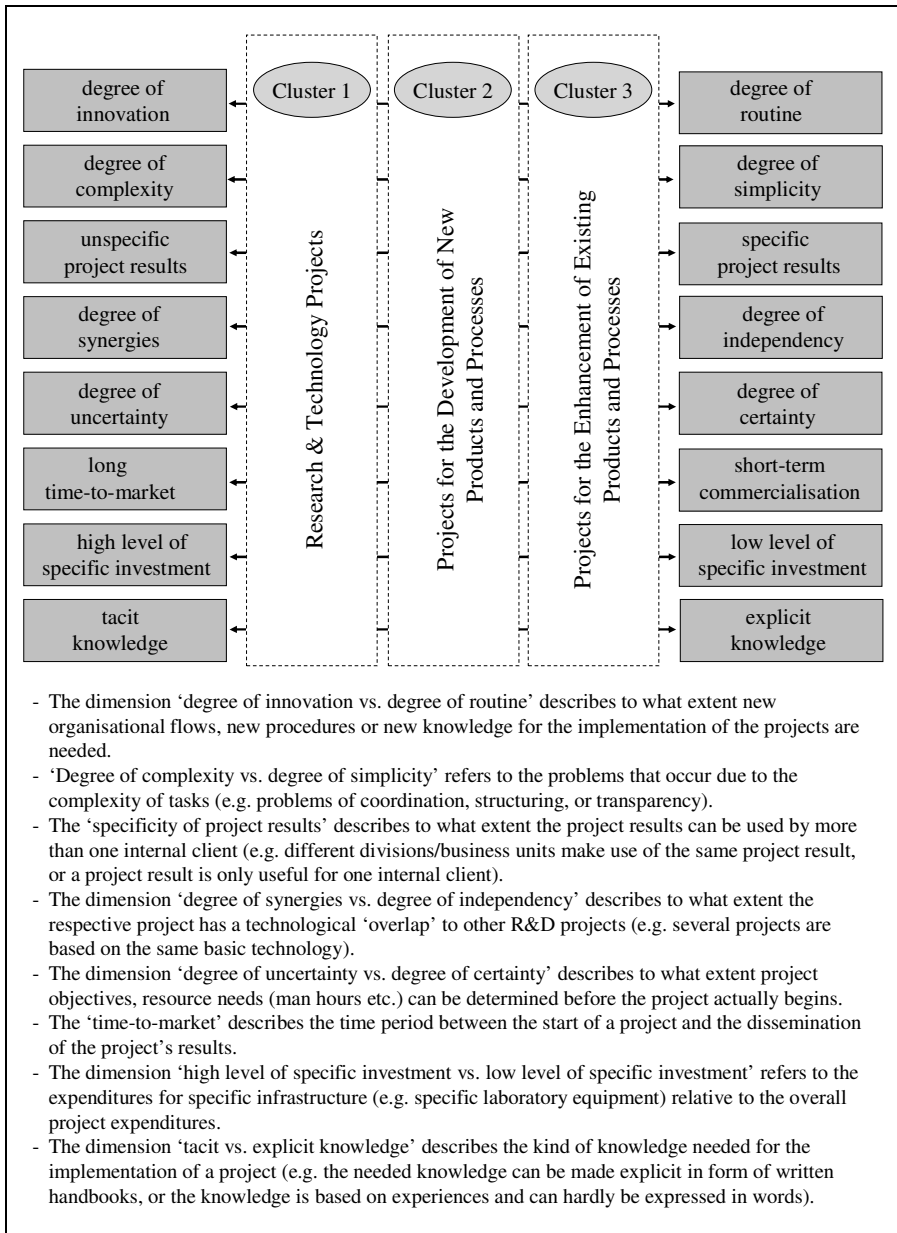


Figure 17: Clusters of R&D project types

R&T projects are usually characterised by a high degree of innovation, a high degree of complexity, unspecific project results, a high degree of synergies, a high degree of uncertainty, a long time-to-market, a high level of specific investment, and a high amount of tacit knowledge.

This is particularly true for R&T projects aimed at opening up new businesses and markets. To a less extent this is true for the predominant part of the R&T projects that are based on existing businesses and markets.

However, projects for the development of new products and processes and particularly projects for the enhancement of existing products and processes are relative to R&T projects characterised by a high degree of routine, a high degree of simplicity, specific project results, a high degree of independency, a high degree of certainty, a high potential for short-term commercialisation, a low level of specific investment, and a high degree of explicit knowledge.

These case study findings in combination with the knowledge from the literature review (see section 2.1) allow creating the following typology of R&D projects presented in Table 6.

<b>Type 1</b>	<b>Research &amp; Technology projects<sup>46</sup></b>
Type 1a	R&T projects aimed at new businesses and markets
Type 1b	R&T projects aimed at existing businesses and markets
<b>Type 2</b>	<b>Projects for the development of new products and processes<sup>47</sup></b>
<b>Type 3</b>	<b>Projects for the enhancement of existing products and processes<sup>48</sup></b>

**Table 6: Typology of R&D projects**

In the following this typology provides the basis for the investigation of the project type-specific differences.

The characteristics of the different types of R&D projects are presented in Table 7.

<sup>46</sup> Objective is to gain insights (e.g. basic research, applied research, methodology research).

<sup>47</sup> Objective is the development of new marketable products/processes.

<sup>48</sup> Objective is the development of product enhancements (derivatives) and process enhancements, based on existing products and processes.

R&D project types \ Characteristics	Type 1a: Research & Technology projects (aimed at new businesses and markets)	Type 1b: Research & Technology projects (aimed at existing businesses and markets)	Type 2: Projects for the Development of New Products and Processes	Type 3: Projects for the Enhancement of Existing Products and Processes
high degree of routine	Not True			True
high degree of simplicity	Not True			True
specific project results	Not True			True
high degree of independency	Not True			True
high degree of certainty	Not True			True
short-term commercialisation	Not True			True
low level of specific investment	Not True			True
high level of explicit knowledge	Not True			True

**Table 7: Characteristics of R&D project types**

On the basis of these findings the central hypothesis H1 can be refined and specified as follows:

H1: There are differences across R&D project types concerning the project characteristics. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a) a higher degree of routine,
- b) a higher degree of simplicity,
- c) more specific project results,
- d) a higher degree of independency,
- e) a higher degree of certainty,
- f) a higher potential for short-term commercialisation,
- g) a lower level of specific investment, and
- h) a higher degree of explicit knowledge.

The implementation of the respective R&D project types often takes place in different organisational arrangements. Thus, in the following section the main findings concerning the R&D organisation are illustrated.

### 4.3 R&D organisation

As the case studies show, there is an organisational separation of research activities on the one hand and development activities on the other hand. Often the research activities are organised in a centralised manner, whereas the development activities predominantly take place decentrally in the divisions and/or business units. Especially the development activities are in relation to the research activities characterised by a higher degree of decentralisation concerning:

- the determination of R&D budgets,
- the project selection, and
- the implementation of projects.

In general, the following two main forms of R&D organisation can be distinguished:

- centralised research and decentralised development,
- decentralised research and decentralised development.

#### Centralised research and decentralised development

This organisational separation shall be illustrated by the example of the R&D organisation at Henkel. The research activities of Henkel are organised centrally and are coordinated by a centralised steering committee. On the other hand every division has its own independent development unit that is set up according to the division's required competencies. Thus, the product development takes place decentrally. The activities of the central research unit focus mainly on 'new markets' and 'new technologies' whereas the product development has its focus on 'existing markets' and 'existing technologies'. Figure 18 illustrates this strategic separation of Henkel's R&D activities.

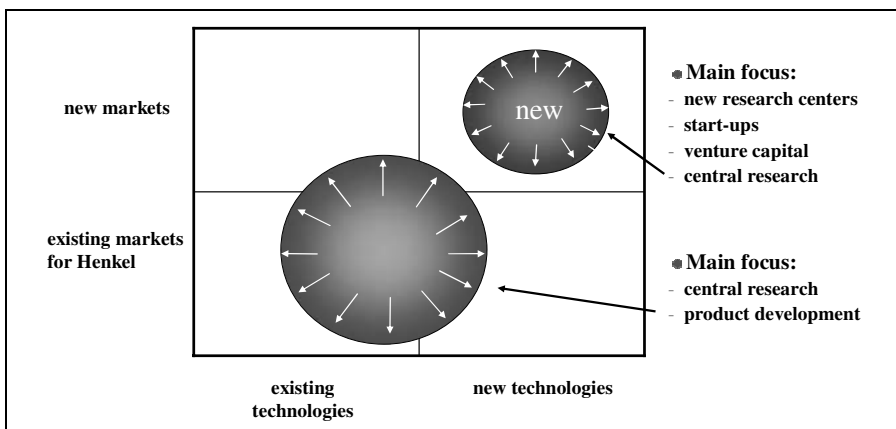
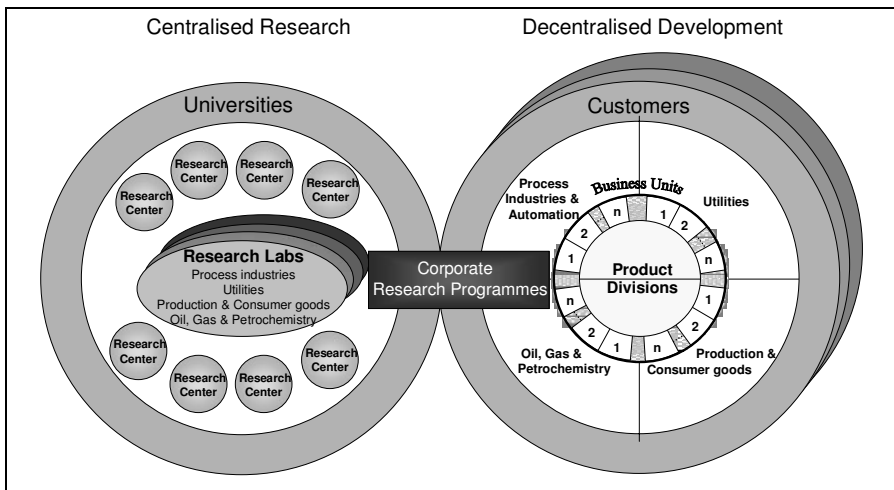


Figure 18: Separation of R&D activities at Henkel

At Henkel the majority of the research activities are bundled in one location (central research). Beside Henkel also BASF, BMW, DaimlerChrysler and Hilti have a central research unit. Often the central research unit is subdivided into technology fields and technology platforms. Of course the mentioned companies also have decentralised research laboratories; however, all the research activities are steered and coordinated by a centralised R&D management. The development activities of these companies are implemented in the decentralised divisions and/or business units (decentral development).

**Decentralised research and decentralised development**

In contrast to the form of R&D organisation described above, the other part of the investigated companies has dispersed research activities at several international locations (decentral research). Companies such as ABB, Abbott, Roche and Syngenta bundle their research activities thematically at several locations in so-called ‘Centers of Excellence’ (CoE) or Research Centers. On the other hand the development activities predominantly take place in the decentralised divisions and/or business units (decentral development). Figure 19 illustrates the organisational separation of R&D activities at ABB, which is oriented on the ABB vision ‘think global, act local’.



**Figure 19: Separation of R&D activities at ABB**

ABB’s R&D activities are globally organised. They comprise the actual product and system development, the customer-specific developments in the divisions as well as the group’s research. The research units have the task to lay the foundations for the subsequent product development in the divisions and business units. In the four global ABB research labs work approximately 800 researchers and in the eight research centers additionally work 1200 researchers. The four research labs of the group coordinate the activities of the research centers within the scope of so-called corporate research programmes.

Furthermore, within this network there is a close cooperation with external partners, such as universities. Each research center represents a certain expertise in a specific technology field. Thus, this expertise is available and can be used in both the research units and the development units of the respective divisions and business units.

After the two major concepts of R&D organisation have been clarified it is now possible to show the findings of the case studies concerning the project type-specific R&D organisation within the investigated companies (see Table 8).

Company	Project categories	Type	Determination of budget	Project selection	Providing unit: Implementation
ABB	Fuzzy Front End projects	1a	C	C	DR
	Projects for the development of technology platforms	1b	C	C	DR
	Product development projects	2	D	D	DD
	Contract development projects	3	D	D	DD
Abbott Laboratories	Breakthrough-Innovation projects	1a+b	C	C	DR
	New Product Development projects	2	D	D	DD
	Line Extensions	3	D	D	DD
BASF	Research & Technology projects	1a+b	C	C	CR
	New product development projects	2	C D	C D	CR DD
	Projects for the development of new and improved processes	2/3	C D	C D	CR DD
	Projects for the enhancement of existing products	3	D	D	DD
BMW	Research and preliminary development projects	1a+b	C	C	CR
	Serial development projects	2	C D	C D	CR DD
	Variants	3	D	D	DD
Daimler Chrysler	Research and preliminary development projects	1a+b	C	C	CR
	Development projects	2	C D	C D	CR DD
	Contract development projects (Variants )	3	D	D	DD
Henkel	Research projects (so-called basic development projects)	1a+b	C	C	CR
	Product development projects	2	C D	C D	CR DD
	Technical services projects	3	D	D	DD
Hilti	Research & Technology projects	1a+b	C	C	CR
	Product development projects	2	C D	C D	CR DD
	Product enhancement projects	3	D	D	DD
Roche	Research & Technology projects	1a+b	C	C	DR
	New product development projects	2	D	D	DD
	Product enhancement projects	3	D	D	DD
Syngenta	Research projects	1a+b	C	C	DR
	Product development projects	2	D	D	DD
	Product enhancement projects	3	D	D	DD

**Table 8: R&D organisation<sup>49</sup>**

<sup>49</sup> The abbreviations of this table express the following terms: C = centralised; D = decentralised; CR = Central Research; DR = Decentral Research; DD = Decentral Development.

Table 8 shows that the organisational separation between research activities on the one hand and development activities on the other hand has implications on the project type-specific determination of budget, the project selection and the implementation of the different project types.

With regard to the case study findings, the central hypothesis H2 can be refined and specified as follows:

H2: There are differences across R&D project types concerning the R&D organisation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by a higher degree of decentralisation concerning:

- a) the determination of R&D budgets,
- b) the project selection, and
- c) the implementation of projects.

Thus far, the project type-specific differences concerning the project characteristics and the R&D organisation were analysed. The following section deals with the project type-specific organisational arrangements concerning the R&D resource allocation.

#### **4.4 R&D resource allocation**

In section 3.2 the conceptual framework of the study was presented, in which a definition for an internal R&D market was developed. In accordance with this framework a market-driven resource allocation is mainly characterised by the following three aspects:

Firstly, there must be at least one supplier and one requestor who interact directly, without the interference of a central decision-committee. Secondly, the demand side directly requests (initiates) certain R&D projects or services from the supplying R&D units. Thirdly, the requestors have to pay a price for the requested R&D projects or services. This in turn implies that the providing unit is a profit center.<sup>50</sup>

Table 9 refers to Table 8, which was shown in the previous section, and expands it with the important aspects mentioned above.

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<sup>50</sup> The profit responsibility of the decentralised development units, indicated in Table 9, refers to the divisions and/or business units to which they are assigned.

Company	Type	R&D resource allocation			
		Internal project initiators: (potential requestors)	Providing unit: (potential suppliers)	Profit responsibility	Financial backer
ABB	1a	MB, DR	DR	CC	CF, VC
	1b	DR, DD, D	DR	CC	CF, D, VC
	2	D	DD	PC	D, VC
	3	D, MC	DD	PC	D, External
Abbott Laboratories	1a+b	MB, DR, DD, D	DR	CC	CF
	2	D	DD	PC	CF
	3	D, MC	DD	PC	D
BASF	1a+b	MB, CR, DD, D	CR	CC	CF, D, VC
	2	CR, D	CR DD	CC PC	CF, D, VC
	2/3	CR, D	CR DD	CC PC	CF, D, VC
	3	D, MC	DD	PC	D, VC
BMW	1a+b	MB, CR, DD, D	CR	CC	CF, VC, External
	2	CR, D	CR DD	CC PC	CF, D, VC, External
	3	D, MC	DD	PC	CF, External
Daimler Chrysler	1a+b	MB, CR, DD, D	CR	CC	CF, D, VC, External
	2	CR, D	CR DD	CC PC	CF, D, VC, External
	3	D, MC	DD	PC	D, External
Henkel	1a+b	MB, CR, DD, D	CR	CC	CF
	2	CR, D	CR DD	CC PC	D
	3	D, MC	DD	PC	D
Hilti	1a+b	MB, CR, DD, D	CR	CC	CF, D
	2	CR, D	CR DD	CC PC	D
	3	DD, D, MC	DD	PC	D
Roche	1a+b	MB, DR, DD, D	DR	CC	CF, D, VC
	2	D	DD	PC	D, VC, External
	3	D, MC	DD	PC	D
Syngenta	1a+b	MB, DR, DD, D	DR	CC	CF
	2	D	DD	PC	CF
	3	D, MC	DD	PC	CF

**Table 9: R&D resource allocation<sup>51</sup>**

Table 9, presented above, gives an overview of the project type-specific differences concerning the R&D resource allocation, and it shows the potential actors of an internal R&D market. As it is shown, the projects of Type 1a are predominantly initiated by the Management Board (MB), which determines the strategic guidelines for the R&D activities. Further initiators of such projects are the respective

<sup>51</sup> The abbreviations of this table express the following terms: MB = Management Board; CR = Central Research; DR = Decentral Research; DD = Decentral Development; D = Division; MC = Marketing Company; CC = Cost Center; PC = Profit Center; VC = Venture Capital; CF = Corporate Funds.

centralised or decentralised research units (CR, DR), respectively, the single researchers of these units. However, the predominant part of Type 1b and Type 2 projects is initiated by the divisions (D), respectively, by the responsible directors of these divisions. The ideas for Type 3 projects often additionally come from the respective marketing companies (MC).

In the context of an internal R&D market the initiators of projects (MB, CR, DR, DD, D, MC) represent the demand side, whereas the providing units (CR, DR, DD) represent the supply side. Thus, all potential supply-demand-relationships can be visualised in form of a supply-demand-matrix. Such a matrix clearly increases the transparency of the company's R&D activities and not yet used synergies can be revealed. However, market-driven exchange relationships are only possible if the involved suppliers and requestors are different actors. This is for example the case if a division assigns the central research to implement a certain research project or if marketing companies ask the R&D units for specific features that enhance the product quality and thus lead to an increased customer satisfaction. On this basis the following two main interfaces for market-like exchange relationships can be identified:

- On the one hand between the requesting divisions/business units and the central research units.
- On the other hand between the units, which are close to markets and customers (e.g. marketing companies), and the R&D units.

Concerning the different types of R&D projects, this means that a market-driven resource allocation is partly possible for Type 1b projects, but especially for the projects of Type 2 and Type 3. For Type 1a projects the application of market-driven forms of resource allocation appears rather impossible, since these projects are often initiated and conducted by the same actors. But even if the involved actors are different it cannot be spoken of a market-driven allocation, since the requesting units usually don't have to pay for the use of the project results; this means that Type 1a projects are mostly financed by corporate funds. Moreover, the research units are normally not profit responsible, since they are organised as cost centers. In contrast to the research units, the decentralised development units, respectively, the divisions and/or business units to which they are assigned, are usually organised as profit centers.

Whereas the development activities in the investigated companies are predominantly financed by the respective divisions, there were discovered some considerable company-specific differences concerning the financing of the research activities. For example, companies such as Syngenta and Henkel completely finance their research activities by corporate funds, whereas at BASF more than 80% of the research budget is determined and also financed through direct assignments from divisions to the central research unit. The financing through external financial backers or via venture capital funds occurs only to a less extent and can be found most often by very long-term and risky research projects.

On the basis of the revealed project type-specific differences the central hypothesis H3 can be refined and specified as follows:

H3: There are differences across R&D project types concerning the application of market-driven forms of resource allocation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a) a stronger interaction of supply and demand,
- b) a higher share of projects that is initiated by the demand side, and
- c) a higher financing share of the requesting divisions/business units.

The remainder of this section presents some illustrative examples of the project type-specific resource allocation from the case studies.

In practice the both extremes ‘Internal Market’ (refer to section 3.2) and ‘Hierarchy’ (refer to section 2.2.1) are usually not applied in their pure form. Nevertheless, they can serve as a reference point in order to evaluate if the applied forms of resource allocation in the respective companies are in tendency rather hierarchical or rather market-driven.

In particular by projects of Type 1a but also of Type 1b the involvement of decision-committees and the application of planning- and control-instruments underline the hierarchical and administrative character of the resource allocation. However, for Type 1b projects, in some companies as for example ABB, BASF, and DaimlerChrysler, also market-like elements, such as direct assignments, are applied.

A mix of hierarchical and market-like elements also characterises the resource allocation processes of Type 2 projects in most of the companies.

Market-like elements, however, are most often applied for projects of Type 3.

Table 10 illustrates the wide range of project type-specific forms of resource allocation, which was found in the case studies.

Project Types	Forms of Resource Allocation	
	Internal Market (M)	Hierarchy (H)
<b>Type 1a:</b> Research & Technology projects (aimed at new businesses and markets)		
<b>Type 1b:</b> Research & Technology projects (aimed at existing businesses and markets)		
<b>Type 2:</b> Projects for the development of new products and processes		
<b>Type 3:</b> Projects for the enhancement of existing products and processes		

**Table 10: Range of applied forms of resource allocation**

For each project type one company is exemplarily positioned in the table shown above. The dotted-line ovals indicate that compared with the mentioned companies there are several companies that apply more hierarchical or more market-driven forms of resource allocation. Likewise, it is shown that the investigated companies apply different forms of resource allocation for the different project types. For R&T projects most of the companies rely on rather hierarchical forms of resource allocation, whereas for development projects and enhancement projects most companies trust in more market-like solutions. To get an in-depth understanding concerning the different forms of resource allocation, the resource allocation processes of the companies mentioned in Table 10 – BASF, Daimler-Chrysler, Syngenta, and Henkel – are explained in more detail.

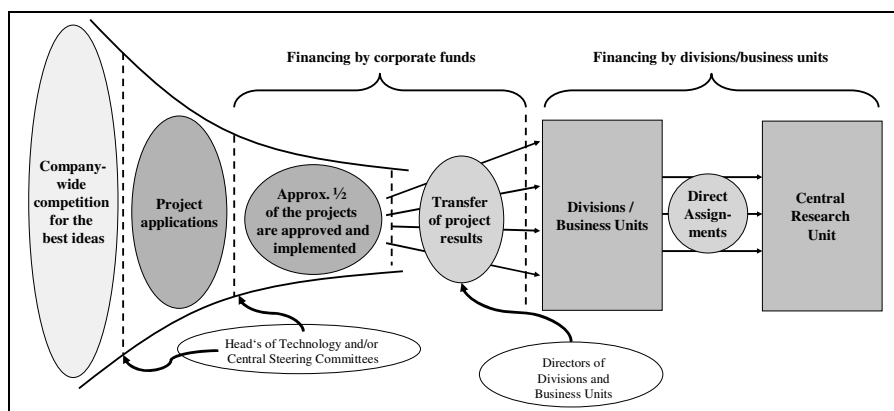
The case studies show that hierarchical forms of resource allocation are applied particularly in the early stages of the innovation process; that means for exploratory R&T projects of Type 1a. It was observed that this is basically true for all the investigated companies. However, there are some companies that also apply some market-like elements for this kind of projects.

The chemical group BASF can serve as an example in this context. At the beginning a company-wide competition for the best ideas takes place. The best ideas of each unit are then developed into project applications. The responsible heads of technology and/or interdisciplinary decision-committees narrow down the choice and the left applications are then sent in to a central steering committee, which decides whether the intended projects are included in the project portfolio of BASF. This steering committee is also responsible for reallocation decisions during the year. Normally about 50% of the project applications are approved and eventually implemented.

The projects are usually conducted in the central research unit and are financed completely by corporate funds. In order to achieve a smooth transfer of the project results into the respective divisions and business units so-called mediators are involved, which are explicitly responsible for the interface management between the central research on the one hand and the divisions and business units on the other hand.

The final transfer decisions are made by the responsible directors of the divisions and business units. The results of these projects should provide the basis for additional R&T projects that the divisions and/or business units, in a next step, can directly assign to the responsible central research unit. However, these projects have to be financed by the requesting divisions and/or business units.

Figure 20 subsequently shows the resource allocation process for Type 1a projects at BASF.



**Figure 20: Resource allocation process for exploratory R&T projects at BASF**

In the context of the transfer of project results a so-called technology/market portfolio plays an outstanding role. It is an instrument designed to support the strategic dialog between the divisions/business units and the R&D units. It is intended to provide help for the allocation of resources and ensure that the product division's strategic objectives are translated more effectively into R&D activities. The technology/market portfolio consists of two component portfolios which should be considered together in strategic discussions:

- The market portfolio provides an overview of BASF's present market position with important products in relation to the relevant competitors and their importance for BASF in terms of sales revenue (possibly also sales volume) and the future attractiveness of the markets.
- The technology portfolio shows the present technological position of BASF in the relevant areas compared with the competitors. It highlights the potential of BASF technologies and the means envisaged to exploit them to the full.

Moreover, a yearly research forum is held on which important research results are presented. Furthermore, the forum aims at generating new project ideas. The discussions and negotiations between potential suppliers and potential requestors, which take place within the scope of this forum, already have a market-like character.

In summary, the outlined resource allocation process is predominantly characterised by hierarchical elements; this is particularly evident in terms of project selection and funding. On the other hand there are also some market-like elements implemented in this process, such as the company-wide competition for the best ideas, the research forum, or the potentially initiated direct assignments.

By R&T projects of Type 1b, in contrast to Type 1a projects, it is in tendency more often the case that market-like elements are applied. In many companies often contracts are made in form of so-called direct assignments; this means that

the respective divisions or business units request certain R&D services from the responsible research units.

In this context DaimlerChrysler can serve as an example for the description of the resource allocation of Type 1b projects: In a first step, each department enters potential project ideas into a database in the Intranet, but initially only the corresponding units have access to the data. After the preliminary selection by the unit heads the left project ideas are forwarded to an interdisciplinary steering committee, which then decides if the project ideas are followed up and if they strategically fit to the overall project portfolio. The complete process as well as the work flows of the research planning can be inferred from Figure 21.

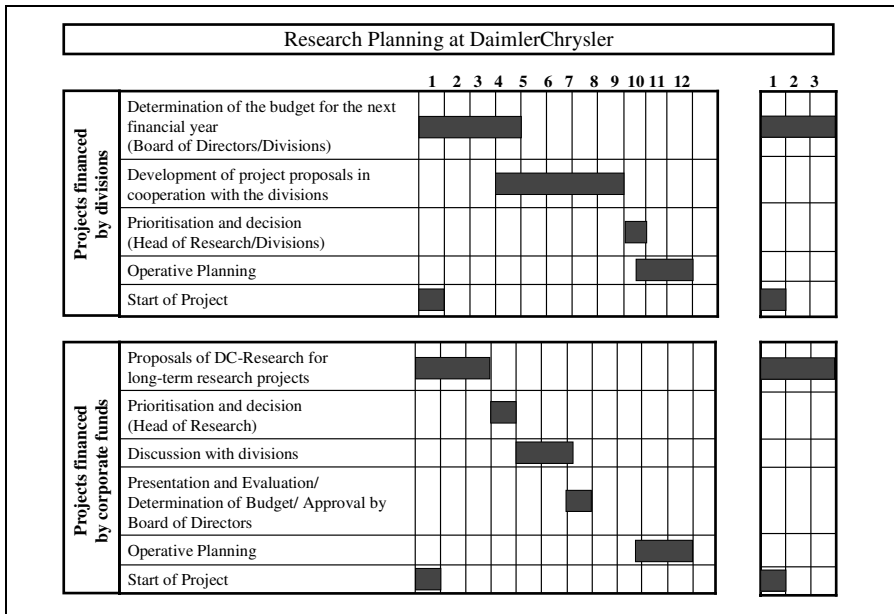


Figure 21: Research planning process at DaimlerChrysler

In spring the research budgets, which the divisions want to demand from the central research, are determined. Then project proposals are developed in form of teamwork between the central research and the divisions. In September the division heads, the head of research and the respective heads of the different technology fields firstly prioritise and then decide on the research projects that are financed by the divisions. This process is shown in the first part of Figure 21 presented above.

The proposals and prioritisations of the other kind of research projects that are financed by corporate funds come from the head of research and the respective heads of the different technology fields. The resulting research plan is then discussed with the divisions before it is approved by the management board. These connections are outlined in the second part of Figure 21 shown above.

In summary, the described process is predominantly organised hierarchically, but there are also some market-like elements that can be identified: Beside the 'market place' for ideas in the Intranet there are further starting points for a market-driven resource allocation. The allocation of resources takes place in form of an acquisition process and the budget that is financed by the divisions is determined within the scope of negotiation processes. Here the divisions in advance pay money into a central research fund. Later the actually requested R&D services are offset against the previously paid money. In principle, the divisions try to avoid paying too much money in advance. Thus, the divisions' financing of research activities and with it the use of previous capacities is getting more uncertain. Through this organisational arrangement the number of direct assignments from the divisions has been considerably increased in recent years. This is particularly due to the fact that the divisions don't have to make binding agreements in advance.

The element of direct assignments is even more applied by projects for the development of new products (Type 2). On top of this is the fact that the requesting divisions and/or business units normally finance this kind of projects. Correspondingly, the development units are profit responsible and often transfer prices are settled. However, also for Type 2 projects there can be found a wide range of organisational arrangements concerning the resource allocation processes.

Exemplaric for a rather hierarchical allocation is the product development process of the agro-chemical firm Syngenta. This company needs about 3-5 years from the idea for a product to completing its market introduction. The process is divided into four stages:

- Stage A: Research/Design Ideas
- Stage B: Evaluation
- Stage C: Product Development
- Stage D: Sales

Stage A (Research/Design Ideas) is concerned with the investigation and generation of a novel product concept. Here it is important to utilise new formulation technology for a specific active ingredient. Eventually, a further task within this stage is to formulate an idea for a product based on business needs and existing technology.

In the subsequent 'Evaluation Stage' (Stage B) it is important to explore, propose options for the development of new products as well as to make a preliminary assessment of these options. Furthermore, the generated concepts must be proved and the technology must be optimised before potential product profiles can be established. At the end of this stage the best product variant has to be selected.

In the ‘Product Development Stage’ (Stage C) the product must be developed and registered in specific territories and markets. Further tasks in this stage are to produce, launch and start selling the product in first markets and finally to monitor customer satisfaction.

The final ‘Sales Stage’ (Stage D) is concerned with the development of the formulation in all markets in order to achieve targeted sales within the shortest time. Further tasks are to optimise exploitation and to provide product support as long as the product is finally phased-out from the Syngenta range.

The flow chart presented in Figure 22 illustrates the single stages in the context of the development process for products.

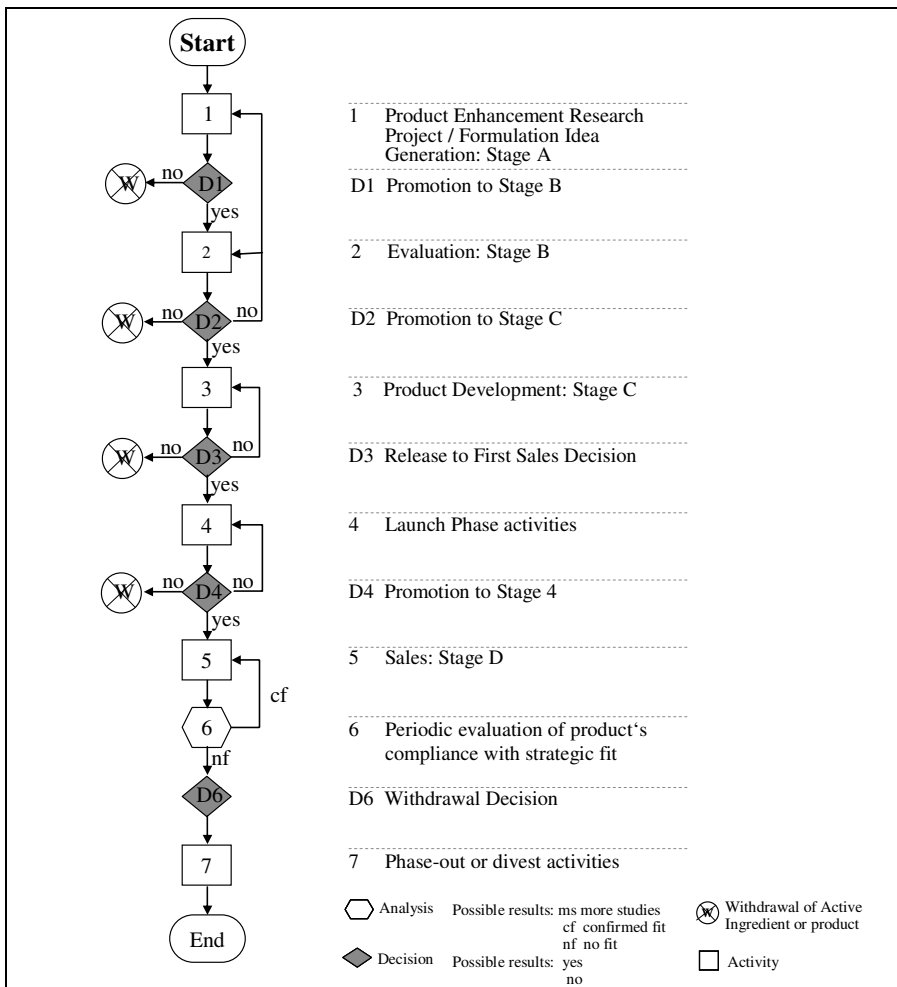
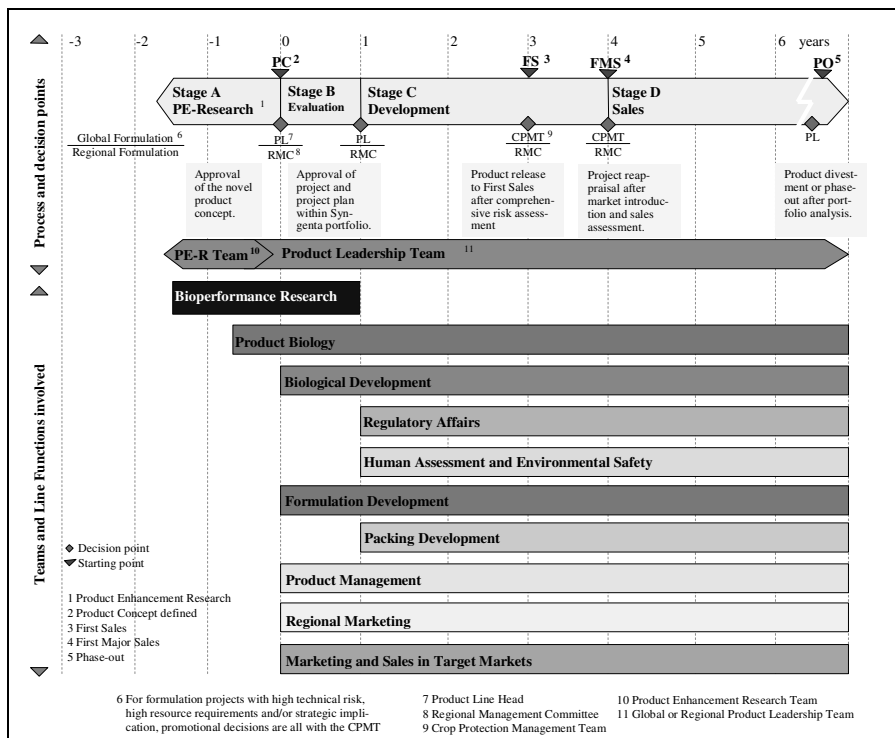


Figure 22: The product development process at Syngenta

At each stage of the described process several line functions have to join forces and work closely together to achieve the progress required (see Figure 23).



**Figure 23: Design of products at Syngenta**

The product development process of Syngenta is exemplary for the hierarchical and administrative organisation of the R&D resource allocation processes. The hierarchical character is shown particularly by the multitude of involved decision-committees, which are responsible for all the important decisions along the product development process.

Table 11 provides an overview of what needs to be decided within the scope of the product development process presented above.

Milestone	Decision Process and Bodies		Main Criteria
	For 'standard' formulation projects	For 'innovative' formulation projects	
<b>Promotion to Stage B (Evaluation)</b>	Decision by the Product Line Head (global) or Regional Management Committee	Commercial approval by the product Line Head Technical review and decision by the Development Committee Notification to the Crop Protection Management Team	Market need / opportunity Potential biological performance Safety aspects Strategic fit
<b>Promotion to Stage C (Product Develop)</b>	Decision by the Product Line Head (global) or Regional Management Committee	Technical approval by the Development Committee Decision by the Crop Protection Management Team	Market need Strategic fit Competitors Biological Performance Safety Profile Regulatory Aspects Technical and Commercial Feasibility
<b>Release to First Sales</b>	Technical approval by the Development Committee (global) or regional equivalent Decision by the Crop Protection Management Team (global) or Regional Management Committee		Biological Performance Potential in Future Markets Commercial Viability Patent Issues Safety Profile Registration Risks Compliance with Company Strategy Portfolio Fit
<b>Promotion to Stage D (Sales)</b>	Technical approval by the Development Committee (global) or regional equivalent Decision by the Crop Protection Management Team (global) or Regional Management Committee		Retrospective Review of Project Plan and Status Market Fit Review Stewardship Aspects
<b>Phase out a product from Syngenta range</b>	Proposal approval by the Product Line Head* (global) Regional Head Product Portfolio Management* Decision by the Product Line Head* or Crop Protection Management Team* *in agreement with Supply Chain Management		Biological Performance Safety and Regulatory Considerations Stewardship Aspects Financial Criteria Availability of the AI Strategic Fit
<b>Responsibility for development projects</b> All products need to be approved by the Global Product Leadership Team and must meet the commercial hurdle rates. The development of a product is generally considered a global responsibility. Formulations that will only be sold in one region and that are not part of the strategic launch platform of an AI may be managed by the relevant region.			Comprehensive documentation is mandatory for each decision point.

**Table 11: Milestones, decision process and bodies, and decision criteria within the development process for new products at Syngenta**

As the case studies show, pure market-driven forms of resource allocation cannot be found in practice. The strongest market-like orientation of the applied resource allocation processes can be identified for Type 3 projects. This is particularly due to the fact that Type 3 projects are projects that are very 'close' to the

market. Moreover, these projects are, relative to Type 2- and particularly Type 1 projects, characterised by a higher degree of routine, a higher degree of certainty, a higher potential for short-term commercialisation etc.

Thus, Type 3 projects can be basically well traded via an internal R&D market, since on the one hand the costs for implementing these projects can be relatively clearly defined and on the other hand the project results can be commercialised in the short run. From the technical point of view as well as from the economical point of view the risks for the involved actors can be well estimated so that the negotiation of prices is in principle facilitated.

Exemplaric for a rather market-driven allocation of R&D resources is the chemical group Henkel. This company has already realised a market-like solution for its 'Services'-projects (Type 3).

The 'Services'-function is assigned to Henkel's R&T division and comprises the following units:

- Corporate Analytical Center,
- Product Safety,
- Henkel Information Center,
- Patents, and
- Engineering.

These units offer their services via an intranet-based service-catalogue to the requesting divisions and business units. In return the requesting units have to pay a price to the supplying service units. The settlement takes place in form of transfer prices. In this context it must be pointed out that these transfer prices are cost-oriented prices and are not the result of negotiations between suppliers and requestors.

The competition in this market-like arrangement can be described as rather strong, since there are a lot of external suppliers that offer the same services. If these external suppliers offer the same quality of service at lower cost the internal requestors are allowed to purchase the needed services externally rather than from the more expensive internal service unit. By applying this form of market-like resource allocation Henkel considerably increased the performance and the service quality of its internal service units.

The example of Henkel shows that market-driven forms of resource allocation, respectively, internal R&D markets have a huge potential to increase efficiency in the R&D field.

The companies' evaluation concerning the project type-specific favourability (effectiveness and/or efficiency) of market-driven forms of resource allocation is shown in the following section.

### 4.5 Allocation result

In order to evaluate the attractiveness of internal R&D markets for the resource allocation, the experts in the companies were asked to give an estimate concerning the project type-specific performance (effectiveness and/or efficiency) of internal market solutions.

To prove the effectiveness of a market-driven allocation design it was asked to what extent direct assignments from requesting units to R&D units lead to a better project selection (effectiveness), in comparison with projects predetermined by committees. This means, that those projects are selected that contribute the highest value (Net Present Value) to the company.

The companies' evaluation concerning the effectiveness of a market-driven resource allocation (on an ordinal five-point scale ranging from very good to very poor) is presented in Table 12.

Project Type:	Effectiveness:				
	Performance of market-driven forms of resource allocation compared to hierarchical forms of resource allocation				
	very good	good	neutral	poor	very poor
<b>Type 1a:</b> Research & Technology projects (aimed at new businesses and markets)					ABB, Abbott Laboratories, BASF, BMW, Daimler Chrysler, Henkel, Hilti, Roche, Syngenta
<b>Type 1b:</b> Research & Technology projects (aimed at existing businesses and markets)		Hilti	ABB, Abbott Laboratories, BASF, Roche, Syngenta	BMW, Daimler Chrysler, Henkel	
<b>Type 2:</b> Projects for the development of new products and processes		ABB, Abbott Laboratories, BASF, Henkel, Hilti, Roche, Syngenta		BMW, Daimler Chrysler	
<b>Type 3:</b> Projects for the enhancement of existing products and processes	ABB, Abbott Laboratories, Roche	BMW, BASF, Daimler Chrysler, Henkel, Hilti, Syngenta			

**Table 12: Evaluation of the effectiveness of market-driven forms of resource allocation**

The evaluation regarding the effectiveness of market-driven forms of resource allocation shows that, by projects of Type 2 and particularly of Type 3, market-driven forms of resource allocation are judged as being more effective than hierarchical forms of resource allocation. For projects of Type 1b the results concerning the effectiveness of the different forms of resource allocation show an undecided picture, whereas by projects of type 1a the hierarchical resource allocation is clearly preferred by all of the investigated companies.

Furthermore, it was examined whether the interplay of supply and demand leads to a more efficient allocation of resources compared to hierarchical forms of resource allocation. For the evaluation of the efficiency of market-driven forms of

resource allocation the companies were asked if the allocation of project resources by supply and demand leads to efficiency improvements in terms of quality, time, and costs.

Table 13 shows the aggregated results in an overview.

Project Type:	Efficiency:				
	Performance of market-driven forms of resource allocation compared to hierarchical forms of resource allocation				
	very good	good	neutral	poor	very poor
<b>Type 1a:</b> Research & Technology projects (aimed at new businesses and markets)		Abbott Laboratories, Hilti, Roche	ABB, BMW, Daimler Chrysler	BASF, Henkel, Syngenta	
<b>Type 1b:</b> Research & Technology projects (aimed at existing businesses and markets)		Abbott Laboratories, Hilti, Roche	ABB, BMW, BASF, Daimler Chrysler	Henkel, Syngenta	
<b>Type 2:</b> Projects for the development of new products and processes		Abbott Laboratories, Hilti, Roche	ABB, BASF, BMW, Daimler Chrysler, Henkel, Syngenta		
<b>Type 3:</b> Projects for the enhancement of existing products and processes		Abbott Laboratories, BMW, Daimler Chrysler, Hilti, Roche	ABB, BASF, Henkel, Syngenta		

**Table 13: Evaluation of the efficiency of market-driven forms of resource allocation**

Concerning the efficiency of market-driven forms of resource allocation, the estimates of the interviewed experts only showed slight project type-specific differences. The estimates are dispersed and quite different within the same project type. However, the average of the answers indicates that market-driven forms of resource allocation compared to hierarchical forms of resource allocation can lead in tendency to a more efficient resource allocation in terms of quality, time, and costs – particularly for Type 3 projects, followed by Type 2- and Type 1 projects.

On the basis of the case study findings presented in this section the central hypothesis H4 can be refined and specified as follows:

H4: There are differences across R&D project types concerning the effectiveness and/or efficiency of market-driven forms of resource allocation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a) a higher effectiveness of direct assignments,
- b) a higher efficiency in terms of an improved adaptability (quality),
- c) a higher efficiency in terms of a shorter resource allocation process (time), and
- d) a higher efficiency in terms of lower costs.

## 4.6 Summary and statement of hypotheses

The main purpose of the case study research was to identify relevant variables, to get a better understanding of the research context, and to refine the basic hypotheses before embarking on the design of a questionnaire for the international survey.

In the following the main case study findings concerning:

- the characteristics of R&D projects,
- the R&D organisation,
- the R&D resource allocation, and
- the allocation result are summarised.

Finally, a statement of testable hypotheses is presented.

### Characteristics of R&D project types

In a first step, it was shown that based on certain characteristics the following three main project types can be distinguished in practice:

- Type 1: Research & Technology projects<sup>52</sup>
  - o Type 1a: R&T projects aimed at new businesses and markets
  - o Type 1b: R&T projects aimed at existing businesses and markets
- Type 2: Projects for the development of new products and processes<sup>53</sup>
- Type 3: Projects for the enhancement of existing products and processes<sup>54</sup>

Because of the fact that most of the investigated companies do not explicitly distinguish between Type 1a projects and Type 1b projects and since these two types of projects are characterised by quite similar characteristics it was decided to combine these two categories into one project type (R&T projects; Type 1) for the subsequently conducted survey.

### R&D organisation

In section 4.3 it was shown that in all of the investigated companies there is an organisational separation between research activities on the one hand and development activities on the other hand. Thereby the research activities are predomi-

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<sup>52</sup> Objective is to gain insights (e.g. basic research, applied research, methodology research).

<sup>53</sup> Objective is the development of new marketable products/processes.

<sup>54</sup> Objective is the development of product enhancements (derivatives) and process enhancements, based on existing products and processes.

nantly organised centrally, whereas the development activities are predominantly organised decentrally in the divisions and/or business units.

Furthermore, it was shown that one part of the companies has a central research unit, in which the research activities are bundled. The other part of the companies has dispersed research activities that are geographically or thematically bundled at several international locations (decentral research).

On this basis it was illustrated that the different project types are implemented in different organisational arrangements. While the budgeting, selection and implementation of Type 1 projects are predominantly organised centrally, the budgeting, selection and implementation of Type 2- and Type 3 projects are predominantly the task of the respective decentralised divisions and/or business units and their development units.

### **R&D resource allocation**

In section 4.4 the initiators/users of R&D services and/or R&D projects were put opposite to the providers of these services, in order to evaluate if resources are allocated in a hierarchic or market-driven way. It was shown that the initiators/users are the potential requestors within the scope of internal R&D markets, whereas the providing units are the potential suppliers.

As further important indicators, for the differentiation between hierarchical and market-driven forms of resource allocation, the profit responsibility of the providing units as well as financing aspects were mentioned. Concerning this, the case studies illustrated that research units are usually cost centers and that Type 1 projects are often financed by corporate funds. In contrast to this, the development units, respectively, the divisions or business units to which they are assigned are usually profit centers and thus profit responsible. And, the corresponding projects of Type 2 and Type 3 are predominantly financed by the requesting units.

On the basis of the gathered data it was shown that depending on the project type different forms of resource allocation are applied. Moreover, it was clarified that market-driven forms of resource allocation are not an established standard in the R&D field. Particularly R&T projects aimed at new businesses and markets (Type 1a) are predominantly coordinated by hierarchical decision-committees. Only some companies sporadically apply market-like elements for this kind of projects. A quite similar picture was shown for the R&T projects aimed at existing businesses and markets (Type 1b). However, most of the companies apply the market-like element of direct assignments for this project type.

Furthermore, the case study research showed that market-like elements are, in tendency, most often applied for Type 2 projects and particularly for Type 3 projects. However, it has to be noted at this juncture that, with regard to the applied forms of resource allocation, there exist a wide range of different allocation designs. This was illustrated by the company-specific examples presented in section 4.4.

**Allocation result**

A differentiated picture was shown in section 4.5 concerning the evaluation of the allocation performance of the alternative forms of resource allocation. For projects of Type 2 and particularly of Type 3 market-driven forms of resource allocation were evaluated as being more effective than hierarchical forms of resource allocation. However, for projects of Type 1 hierarchical solutions were favoured.

Concerning the efficiency, the case studies showed a less clear picture. But, in tendency the experts in the companies saw some potential to increase efficiency by establishing internal R&D markets – especially for Type 3- and Type 2 projects.

On the basis of the case study findings, presented in this chapter, the following hypotheses were formulated (see Table 14).

<p>Characteristics of R&amp;D project types</p>	<p>H1: There are differences across R&amp;D project types concerning the project characteristics. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:</p> <ul style="list-style-type: none"> <li>a) a higher degree of routine,</li> <li>b) a higher degree of simplicity,</li> <li>c) more specific project results,</li> <li>d) a higher degree of independency,</li> <li>e) a higher degree of certainty,</li> <li>f) a higher potential for short-term commercialisation,</li> <li>g) a lower level of specific investment, and</li> <li>h) a higher degree of explicit knowledge.</li> </ul>
<p>R&amp;D organisation</p>	<p>H2: There are differences across R&amp;D project types concerning the R&amp;D organisation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by a higher degree of decentralisation concerning:</p> <ul style="list-style-type: none"> <li>a) the determination of R&amp;D budgets,</li> <li>b) the project selection, and</li> <li>c) the implementation of projects.</li> </ul>
<p>R&amp;D resource allocation</p>	<p>H3: There are differences across R&amp;D project types concerning the application of market-driven forms of resource allocation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:</p> <ul style="list-style-type: none"> <li>a) a stronger interaction of supply and demand,</li> <li>b) a higher share of projects that is initiated by the demand side, and</li> <li>c) a higher financing share of the requesting divisions/business units.</li> </ul>
<p>Allocation result</p>	<p>H4: There are differences across R&amp;D project types concerning the effectiveness and/or efficiency of market-driven forms of resource allocation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:</p> <ul style="list-style-type: none"> <li>a) a higher effectiveness of direct assignments,</li> <li>b) a higher efficiency in terms of an improved adaptability (quality),</li> <li>c) a higher efficiency in terms of a shorter resource allocation process (time),</li> <li>d) a higher efficiency in terms of lower costs.</li> </ul>

**Table 14: Statement of hypotheses**

In summary it may be said that the hypotheses stated above were based on the literature review (chapter 2), the conceptual framework (section 3.2) and the empirical findings of the case studies. They illustrate the relationships between the variables of the underlying research model, which was presented in section 3.6.1. The formulated hypotheses were tested within the scope of an international survey. The corresponding hypothesis-tests and the findings of the survey are discussed in the subsequent chapter.

## 5 Findings of the survey

### 5.1 Introduction

In the following sections the findings of the survey are presented. The methodological issues associated with the survey research were already discussed in section 3.6.

Within the scope of this empirical study a written postal survey was used as the basic research method. Questionnaires were sent to 281 huge R&D-intensive companies worldwide, which were mainly selected from the Fortune Global 500 Database. Thereby it was focused on the technology-intensive industries automotive, chemicals, electronics, pharmaceuticals, and telecommunications. In total 45 companies participated in the study, which meant a response-rate of 16.01%.

Subsequently, the criteria R&D quota, R&D budget, and R&D co-workers are used to illustrate the structure of the sample.

Figure 24 presents the technology-intensity of the participating companies compared with their R&D quota (R&D expenses in relation to turnover).

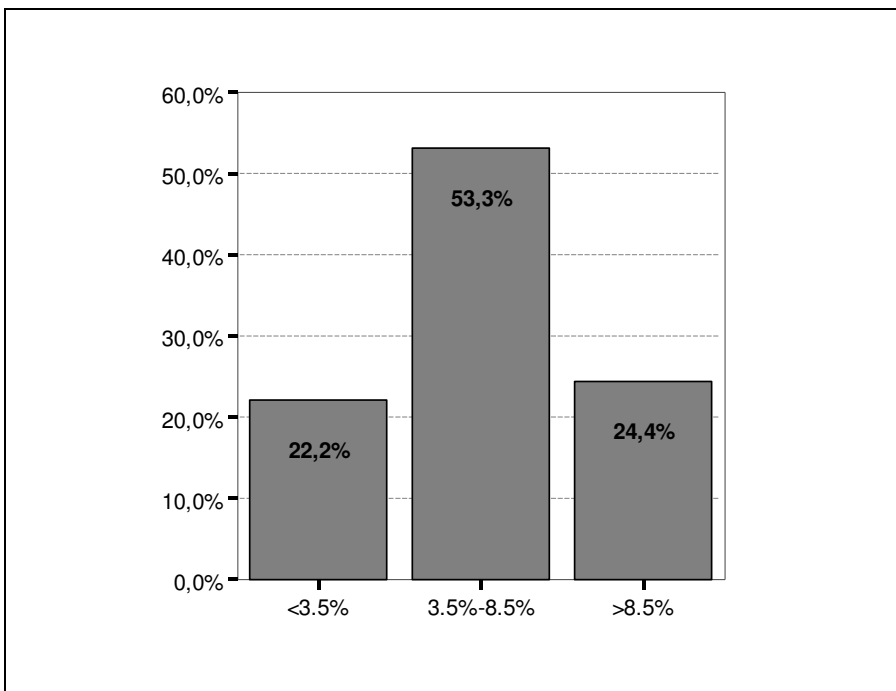
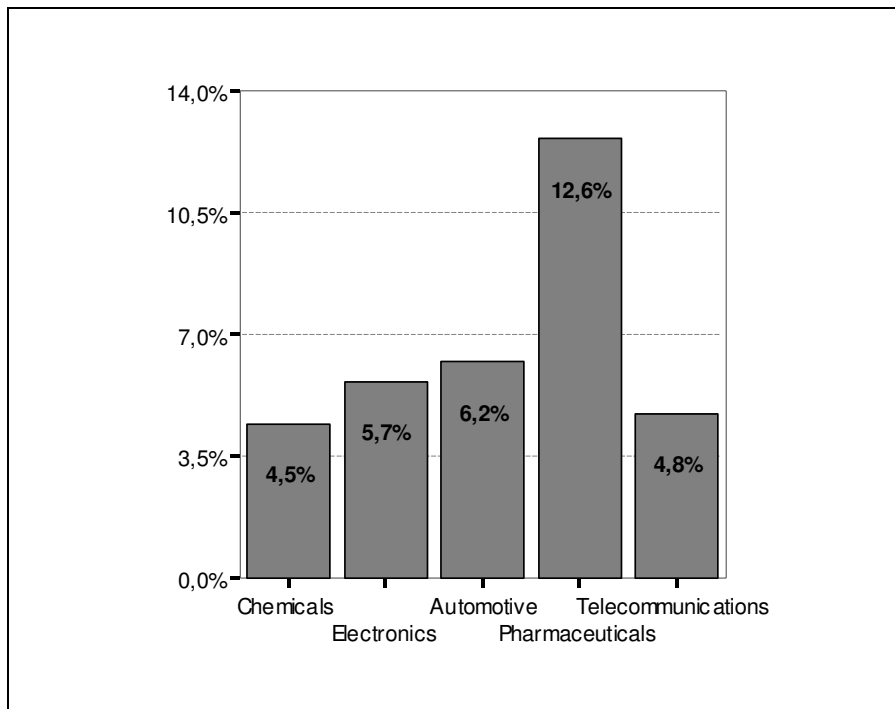


Figure 24: Sample characteristic – R&D quota

The frequency distribution illustrates that the predominant part of the participating companies (77.7%) have a R&D quota which lies above the 3.5% level. The answers of the 45 companies resulted in a mean value of 6.5%.<sup>55</sup> With regard to the R&D expenses, 22.2% of the companies stated that their R&D quota is smaller than 3.5%. On the other hand 24.4% of the companies have a R&D quota of more than 8.5%. These companies belong mainly to the pharmaceuticals industry.

This is also illustrated by Figure 25 which shows the related average R&D quota by industry.

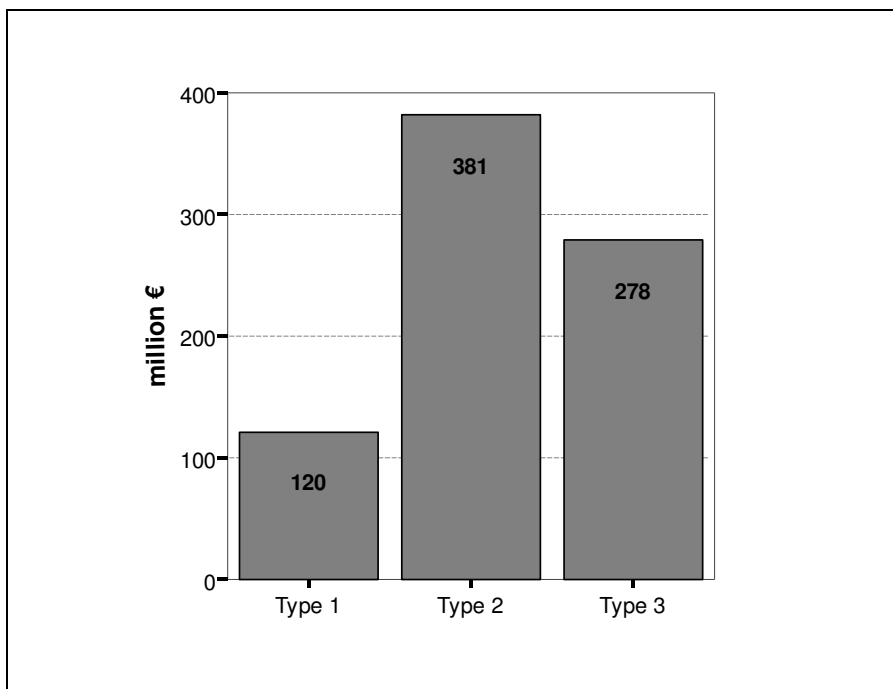


**Figure 25: Average R&D quota by industry**

Figure 25 shows that the pharmaceutical industry with more than 12 percent has a noticeably higher R&D quota than the other industries. But all industries can be described as being high technology-industries, since their average R&D quota lies above the 3.5% level (NIW et al., 1996).

Moreover, it was analysed how the total R&D budget is distributed among the different types of R&D projects. The corresponding results are shown in Figure 26.

<sup>55</sup> The corresponding standard deviation was 4.52%.



**Figure 26: Sample characteristic – R&D budget**

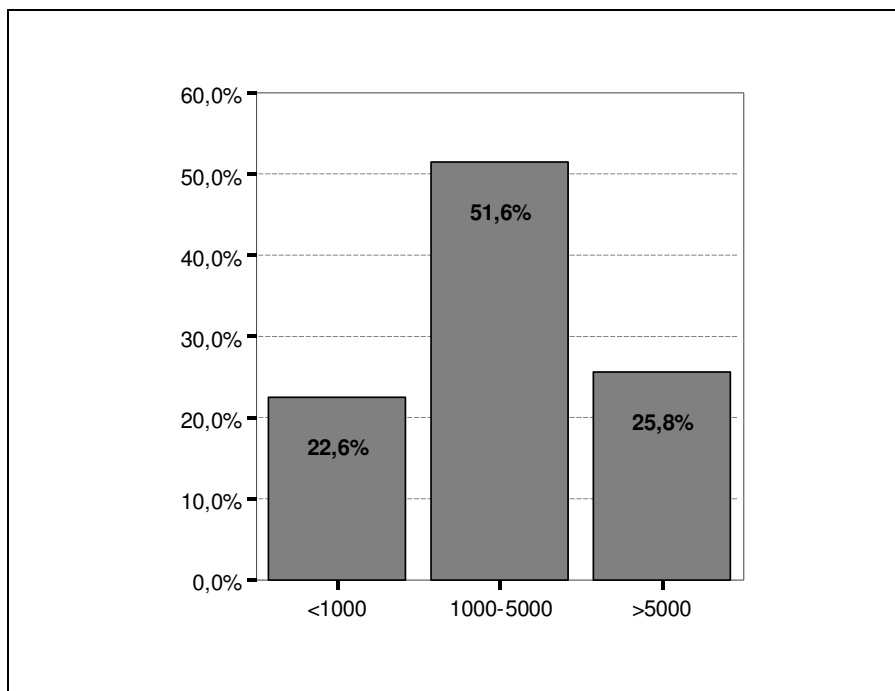
The total average R&D budget of the investigated companies was 779 million €. On average 120 million € thereof were invested in Research & Technology projects (Type 1), 381 million € were spent for the development of new products and processes (Type 2) and 278 million € flew into projects for the enhancement of existing products and processes (Type 3).<sup>56</sup>

These figures show that the predominant part of total R&D budgets (approximately 85%) is pumped into development and enhancement activities, i.e. into activities that promise positive cash flows in the medium-term, respectively, in the short-term. However, only about 15% of total R&D budgets are used for research activities, i.e. for activities that mainly aim at securing the long-term growth and success of companies.

Beside R&D quota and R&D budget, the number of R&D co-workers was considered as a major characteristic of the sample. Figure 27 shows the corresponding frequency distribution.

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<sup>56</sup> The corresponding standard deviations were 182 million € (Type 1), 491 million € (Type 2), and 400 million € (Type 3).



**Figure 27: Sample characteristic – R&D co-workers**

On average the 45 companies employed 4252 R&D co-workers in their R&D units.<sup>57</sup> With regard to the number of R&D co-workers, the raised data showed that 22.6% of the companies have less than 1000 R&D co-workers, 51.6% have between 1000 and 5000 R&D co-workers, and 25.8% of the surveyed companies are characterised by more than 5000 R&D co-workers.

Given the sample characteristics described above, the following sections deal with the descriptive and bivariate analysis of the raised data. According to the structure of the designed research model (see section 3.6.1) and the questionnaire (see appendix 2) the analysis mainly focuses on the exploration of project type-specific differences concerning the following aspects:

- Characteristics of R&D project types (section 5.2),
- R&D organisation (section 5.3),
- R&D resource allocation (section 5.4), and
- Allocation result (section 5.5).

Finally, the survey results are summarised and discussed in section 5.6.

<sup>57</sup> The corresponding standard deviation was 5939.

## 5.2 Characteristics of R&D project types

Based on the insights of the literature review (chapter 2) and the findings of the case studies (chapter 4) the following typology of R&D projects was created (refer to section 4.2):

- Research & Technology projects (Type 1)
- Projects for the development of new products and processes (Type 2)
- Projects for the enhancement of existing products and processes (Type 3)

Within the scope of the survey it was investigated by which characteristics the above-mentioned project types can be differentiated. Thus, the test of the following hypothesis had main emphasis:

H1: There are differences across R&D project types concerning the project characteristics. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a) a higher degree of routine,
- b) a higher degree of simplicity,
- c) more specific project results,
- d) a higher degree of independency,
- e) a higher degree of certainty,
- f) a higher potential for short-term commercialisation,
- g) a lower level of specific investment, and
- h) a higher degree of explicit knowledge.

Therefore, in a first step, it was asked if the project types are characterised by a high degree of innovation; or the other way round: to what extent the different project types are characterised by a high **degree of routine**.

The corresponding survey results are presented in Table 15.

<b>Crosstab</b>						
			degree of routine			Total
			Low	Middle	High	
project type	Type 1	Count	38	4	3	45
		Expected Count	28,8	8,5	7,8	45,0
		% within project type	84,4%	8,9%	6,7%	100,0%
		Std. Residual	1,7	-1,5	-1,7	
	Type 2	Count	31	10	3	44
		Expected Count	28,1	8,3	7,6	44,0
		% within project type	70,5%	22,7%	6,8%	100,0%
		Std. Residual	,5	,6	-1,7	
	Type 3	Count	16	11	17	44
		Expected Count	28,1	8,3	7,6	44,0
		% within project type	36,4%	25,0%	38,6%	100,0%
		Std. Residual	-2,3	,9	3,4	
Total	Count	85	25	23	133	
	Expected Count	85,0	25,0	23,0	133,0	
	% within project type	63,9%	18,8%	17,3%	100,0%	

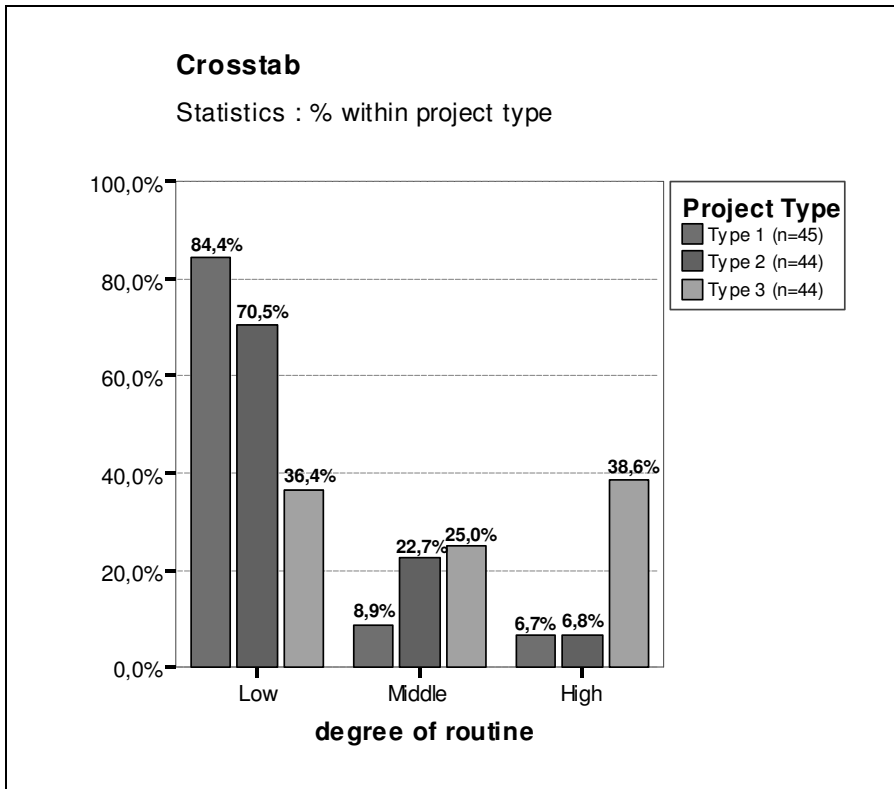
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	29,421 <sup>a</sup>	4	,000
Likelihood Ratio	29,284	4	,000
Linear-by-Linear Association	23,678	1	,000
N of Valid Cases	133		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7,61.

**Table 15: Crosstabulation – degree of routine**

In general, the results showed that especially the projects of Type 1 and Type 2 are characterised by a high degree of innovation. Put differently, projects of Type 1 were only in 6.7% of the cases and projects of Type 2 only in 6.8% of the cases characterised by a high degree of routine. Compared to projects of Type 1 and Type 2, projects of Type 3 (38.6%) were characterised by a significantly higher degree of routine.

The corresponding frequency distribution is shown in Figure 28.



**Figure 28: Frequency distribution – degree of routine**

Obviously there seems to be an association between the different project types and the degree of routine. This is also indicated by the conducted chi-squared test ( $\chi^2_{(4,133)}=29.421; p<.000$ ). Relative to Type 2 projects and particularly Type 1 projects, Type 3 projects are characterised by the highest degree of routine. The hypothesis H1a can thus be confirmed.

Moreover, it was asked if problems occur during the implementation of projects, because of the complexity of tasks; or put differently: to what extent the different project types are characterised by a high **degree of simplicity**.

The results concerning the degree of simplicity of the different types of R&D projects are shown in Table 16.

<b>Crosstab</b>						
			degree of simplicity			Total
			Low	Middle	High	
project type	Type 1	Count	13	16	15	44
		Expected Count	16,3	12,0	15,7	44,0
		% within project type	29,5%	36,4%	34,1%	100,0%
		Std. Residual	-,8	1,2	-,2	
	Type 2	Count	21	13	10	44
		Expected Count	16,3	12,0	15,7	44,0
		% within project type	47,7%	29,5%	22,7%	100,0%
		Std. Residual	1,2	,3	-1,4	
	Type 3	Count	15	7	22	44
		Expected Count	16,3	12,0	15,7	44,0
		% within project type	34,1%	15,9%	50,0%	100,0%
		Std. Residual	-,3	-1,4	1,6	
Total	Count	49	36	47	132	
	Expected Count	49,0	36,0	47,0	132,0	
	% within project type	37,1%	27,3%	35,6%	100,0%	

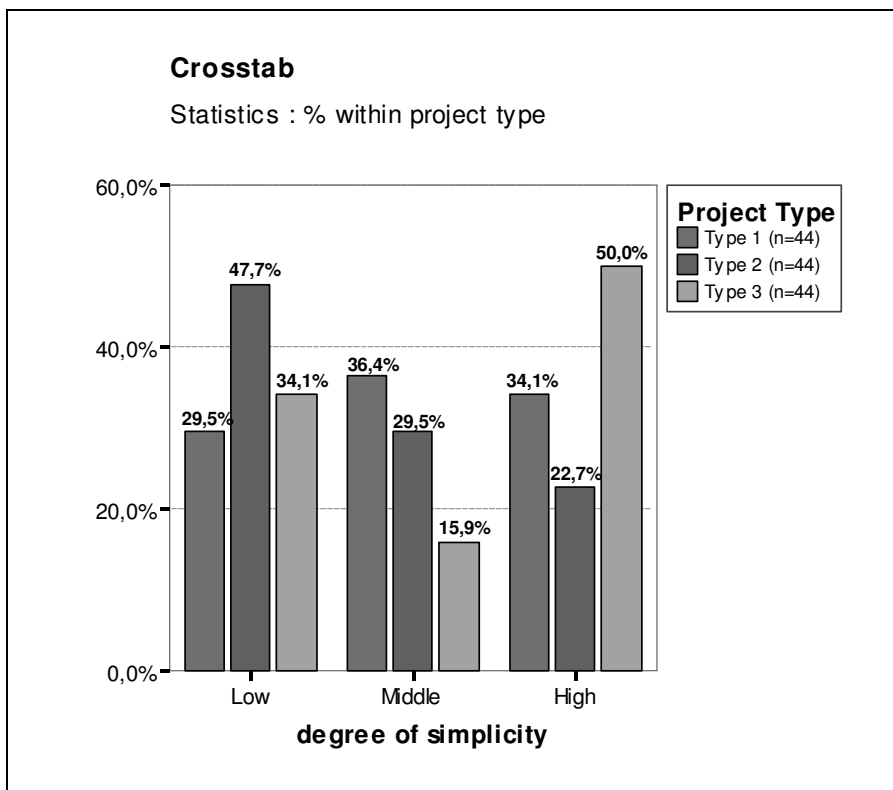
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10,261 <sup>a</sup>	4	,036
Likelihood Ratio	10,461	4	,033
Linear-by-Linear Association	,388	1	,533
N of Valid Cases	132		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 12,00.

**Table 16: Crosstabulation – degree of simplicity**

The respondents stated that Type 1 projects are in 34.1% of the cases characterised by a high degree of simplicity. For Type 2 projects this was the case in 22.7% and for Type 3 projects in 50.0% of the observations.

The corresponding frequency distribution is shown in Figure 29.



**Figure 29: Frequency distribution – degree of simplicity**

Figure 29 shows that Type 3 projects have the relatively highest degree of simplicity, followed by Type 1 projects and Type 2 projects. The corresponding chi-squared test ( $\chi^2_{(4,132)}=10.261; p<.036$ ) indicates a significant association between the project type and the degree of simplicity. However, not in the way expected since Type 1 projects have a higher degree of simplicity than Type 2 projects. Thus, on the basis of the survey data, the initial hypothesis H1b cannot be confirmed.

Furthermore, it was asked if the project results are normally used by more than one internal client (division/business unit etc.). The project type-specific **specificity of project results** is shown in Table 17.

Crosstab						
			specificity of project results			Total
			Low	Middle	High	
project type	Type 1	Count	30	2	13	45
		Expected Count	22,3	3,7	19,0	45,0
		% within project type	66,7%	4,4%	28,9%	100,0%
		Std. Residual	1,6	-,9	-,14	
	Type 2	Count	21	5	19	45
		Expected Count	22,3	3,7	19,0	45,0
		% within project type	46,7%	11,1%	42,2%	100,0%
		Std. Residual	-,3	,7	,0	
	Type 3	Count	16	4	25	45
		Expected Count	22,3	3,7	19,0	45,0
		% within project type	35,6%	8,9%	55,6%	100,0%
		Std. Residual	-1,3	,2	1,4	
Total	Count	67	11	57	135	
	Expected Count	67,0	11,0	57,0	135,0	
	% within project type	49,6%	8,1%	42,2%	100,0%	

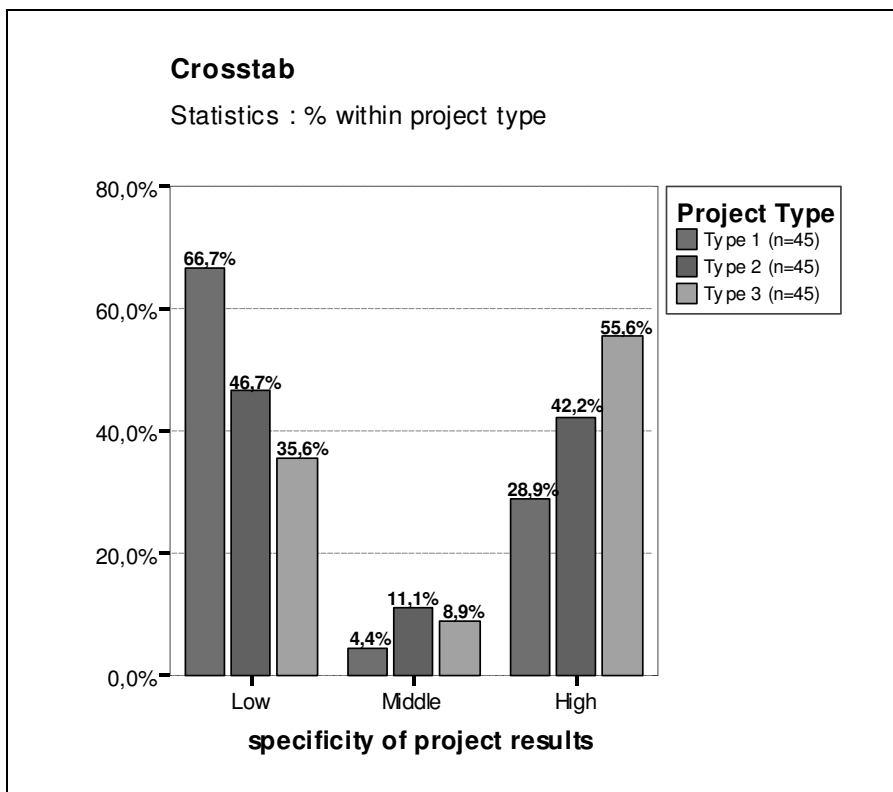
Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9,570 <sup>a</sup>	4	,048
Likelihood Ratio	9,678	4	,046
Linear-by-Linear Association	8,166	1	,004
N of Valid Cases	135		

a. 3 cells (33,3%) have expected count less than 5. The minimum expected count is 3,67.

**Table 17: Crosstabulation – specificity of project results**

The data from the survey showed that Type 1 projects are in 28.9% of the cases characterised by a high degree of specificity of project results. For projects of Type 2 this was valid in 42.2% of the cases and for projects of Type 3 in 55.6% of the cases.

The corresponding frequency distribution is shown in Figure 30.



**Figure 30: Frequency distribution – specificity of project results**

The conducted chi-squared test indicates that there exist some project type-specific differences concerning the variable ‘specificity of project results’ ( $\chi^2_{(4,135)}=9.570; p<.048$ ). Relative to Type 2 projects and particularly Type 1 projects, the project results of Type 3 projects are most specific. On this basis the hypothesis H1c can be confirmed. However, it has to be noted that the statistical results are only marginally significant.

Likewise, it was asked if there is a very high technological ‘overlap’ between the individual projects; or put differently: to what extent the different project types are characterised by a high **technological independency**.

The corresponding survey results are presented in Table 18.

Crosstab						
			technological independency between projects			Total
			Low	Middle	High	
project type	Type 1	Count	19	8	18	45
		Expected Count	21,7	8,7	14,7	45,0
		% within project type	42,2%	17,8%	40,0%	100,0%
		Std. Residual	-,6	-,2	,9	
	Type 2	Count	25	9	11	45
		Expected Count	21,7	8,7	14,7	45,0
		% within project type	55,6%	20,0%	24,4%	100,0%
		Std. Residual	,7	,1	-1,0	
	Type 3	Count	21	9	15	45
		Expected Count	21,7	8,7	14,7	45,0
		% within project type	46,7%	20,0%	33,3%	100,0%
		Std. Residual	-,1	,1	,1	
Total	Count	65	26	44	135	
	Expected Count	65,0	26,0	44,0	135,0	
	% within project type	48,1%	19,3%	32,6%	100,0%	

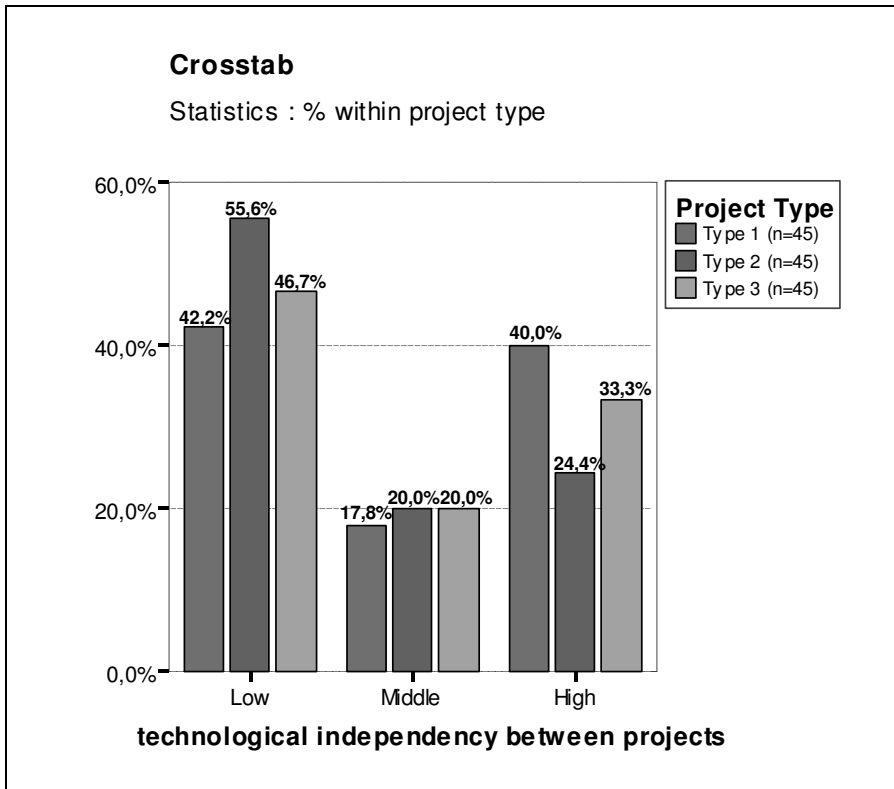
Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2,620 <sup>a</sup>	4	,623
Likelihood Ratio	2,647	4	,618
Linear-by-Linear Association	,352	1	,553
N of Valid Cases	135		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 8,67.

**Table 18: Crosstabulation – technological independency between projects**

The survey participants stated that Type 1 projects are in 40.0% of the cases characterised by a high technological independency between projects. For projects of Type 2 this was the case in 24.4% and for projects of Type 3 in 33.3% of the observations.

The corresponding frequency distribution is shown in Figure 31.



**Figure 31: Frequency distribution – technological independency between projects**

Figure 31 shows only slight project type-specific differences. Thus, the conducted chi-squared test indicates that there does not exist a statistically significant association between the project type and the variable ‘technological independency between projects’ ( $\chi^2_{(4,135)}=2.620$ ;  $p<.623$ ). Therefore, the hypothesis H1d cannot be confirmed.

Concerning the **degree of certainty**, it was asked what percent of project objectives, resource needs (man hours etc.) can be determined before the project actually begins.

With regard to this aspect, the survey raised the following answers presented in Table 19.

Crosstab						
			degree of certainty			Total
			Low	Middle	High	
project type	Type 1	Count	9	15	20	44
		Expected Count	3,7	8,0	32,3	44,0
		% within project type	20,5%	34,1%	45,5%	100,0%
		Std. Residual	2,8	2,5	-2,2	
	Type 2	Count	2	5	37	44
		Expected Count	3,7	8,0	32,3	44,0
		% within project type	4,5%	11,4%	84,1%	100,0%
		Std. Residual	-,9	-1,1	,8	
	Type 3	Count	0	4	40	44
		Expected Count	3,7	8,0	32,3	44,0
		% within project type	,0%	9,1%	90,9%	100,0%
		Std. Residual	-1,9	-1,4	1,3	
Total	Count	11	24	97	132	
	Expected Count	11,0	24,0	97,0	132,0	
	% within project type	8,3%	18,2%	73,5%	100,0%	

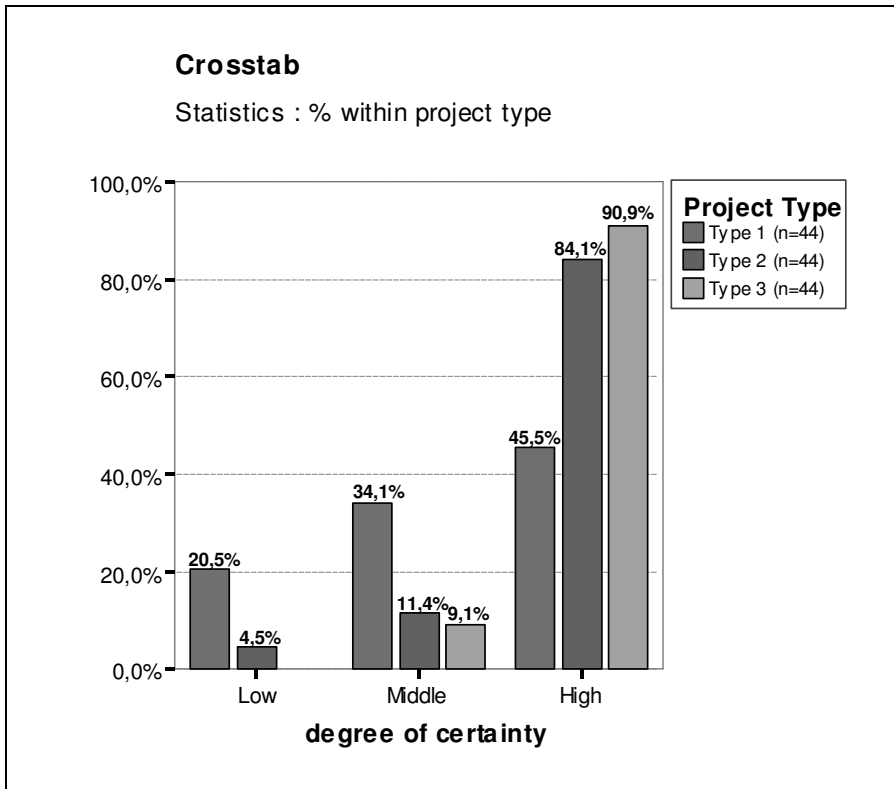
Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	28,628 <sup>a</sup>	4	,000
Likelihood Ratio	30,136	4	,000
Linear-by-Linear Association	24,090	1	,000
N of Valid Cases	132		

a. 3 cells (33,3%) have expected count less than 5. The minimum expected count is 3,67.

**Table 19: Crosstabulation – degree of certainty**

The analysis of the survey data revealed that Type 1 projects were in 45.5% of the cases characterised by a high degree of certainty. For Type 2 projects this was the case in 84.1% and for Type 3 projects in 90.9% of the observations.

The corresponding frequency distribution is shown in Figure 32.



**Figure 32: Frequency distribution – degree of certainty**

Type 3 projects are characterised by the highest degree of certainty, followed by Type 2 projects and Type 1 projects. This association is also indicated by the conducted chi-squared test ( $\chi^2_{(4,132)}=28.628$ ;  $p<.000$ ). Thus, the hypothesis H1e can be confirmed.

Concerning the question how long the projects last from inception to dissemination of results (**time-to-market**), the following answers were received (refer to the crosstabulation presented in Table 20).

Crosstab						
			potential for short-term commercialisation			Total
			Low	Middle	High	
project type	Type 1	Count	13	18	14	45
		Expected Count	5,0	8,7	31,3	45,0
		% within project type	28,9%	40,0%	31,1%	100,0%
		Std. Residual	3,6	3,2	-3,1	
	Type 2	Count	2	7	36	45
		Expected Count	5,0	8,7	31,3	45,0
		% within project type	4,4%	15,6%	80,0%	100,0%
		Std. Residual	-1,3	-,6	,8	
	Type 3	Count	0	1	44	45
		Expected Count	5,0	8,7	31,3	45,0
		% within project type	,0%	2,2%	97,8%	100,0%
		Std. Residual	-2,2	-2,6	2,3	
Total	Count	15	26	94	135	
	Expected Count	15,0	26,0	94,0	135,0	
	% within project type	11,1%	19,3%	69,6%	100,0%	

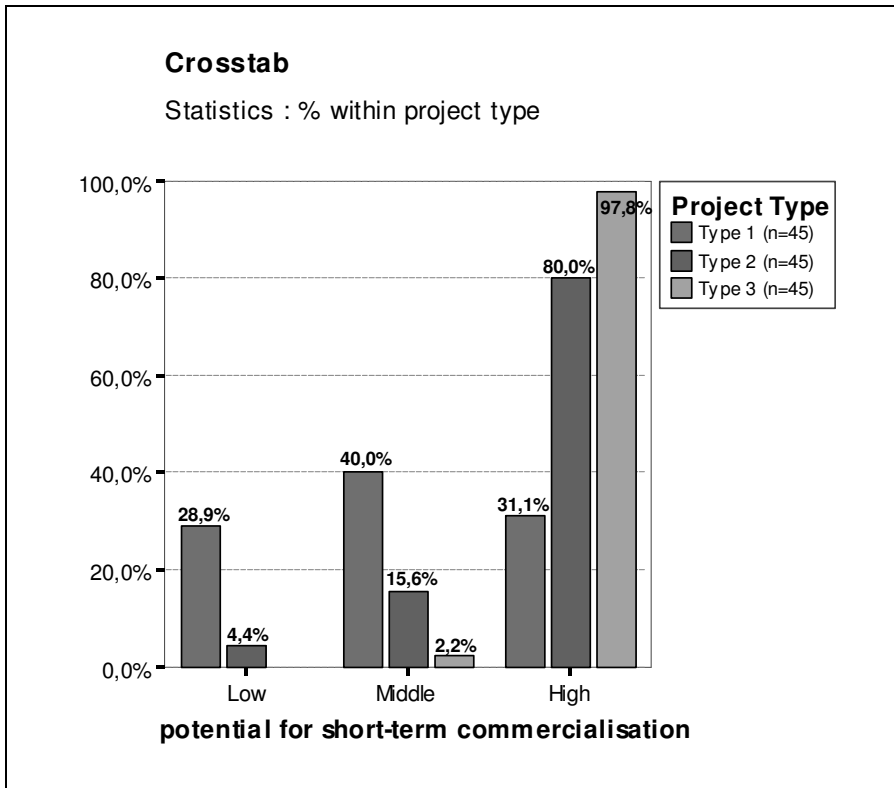
Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	52,158 <sup>a</sup>	4	,000
Likelihood Ratio	57,496	4	,000
Linear-by-Linear Association	43,858	1	,000
N of Valid Cases	135		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,00.

**Table 20: Crosstabulation – time-to-market**

The respondents stated that Type 1 projects are in 31.1% of the cases characterised by a high potential for short-term commercialisation (time-to-market <2 years). For Type 2 projects this answer was given in 80.0% of the cases and for Type 3 projects in 97.8% of the cases.

The corresponding frequency distribution is shown in Figure 33.



**Figure 33: Frequency distribution – time-to-market**

Concerning the potential for short-term commercialisation, the conducted chi-squared test indicates significant project type-specific differences ( $\chi^2_{(4,135)}=52.158$ ;  $p<.000$ ). Projects of Type 3 are characterised by the shortest time-to-market, followed by Type 2- and Type 1 projects. On this basis the hypothesis H1f can be confirmed.

Moreover, it was asked what the expenditures for specific infrastructure (e.g. specific laboratory equipment) are, compared to the overall project expenditures; or in other words: to what extent the **existing infrastructure** is sufficient for the implementation of projects.

Based on the corresponding survey results the following crosstabulation was created (see Table 21).

<b>Crosstab</b>						
			usage of existing infrastructure			Total
			Low	Middle	High	
project type	Type 1	Count	1	8	35	44
		Expected Count	1,7	4,8	37,5	44,0
		% within project type	2,3%	18,2%	79,5%	100,0%
		Std. Residual	-,5	1,5	-,4	
	Type 2	Count	4	2	36	42
		Expected Count	1,6	4,6	35,8	42,0
		% within project type	9,5%	4,8%	85,7%	100,0%
		Std. Residual	1,8	-1,2	,0	
	Type 3	Count	0	4	38	42
		Expected Count	1,6	4,6	35,8	42,0
		% within project type	,0%	9,5%	90,5%	100,0%
		Std. Residual	-1,3	-,3	,4	
Total	Count	5	14	109	128	
	Expected Count	5,0	14,0	109,0	128,0	
	% within project type	3,9%	10,9%	85,2%	100,0%	

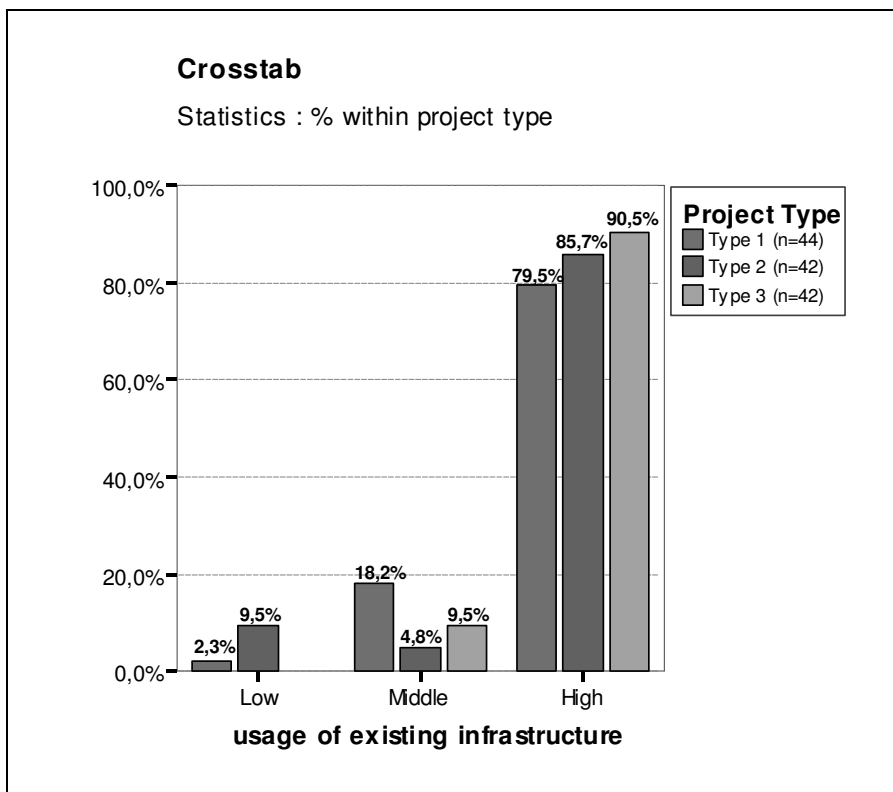
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9,290 <sup>a</sup>	4	,054
Likelihood Ratio	10,049	4	,040
Linear-by-Linear Association	1,584	1	,208
N of Valid Cases	128		

a. 6 cells (66,7%) have expected count less than 5. The minimum expected count is 1,64.

**Table 21: Crosstabulation – usage of existing infrastructure**

In 79.5% of the cases the respondents stated that Type 1 projects can be implemented on the basis of existing infrastructure. For Type 2 projects this was stated in 85.7% of the cases and for Type 3 projects in 90.5% of the cases.

The corresponding frequency distribution is shown in Figure 34.



**Figure 34: Frequency distribution – usage of existing infrastructure**

Figure 34 shows only slight project type-specific differences. Correspondingly, the conducted chi-squared test indicates that there does not exist a statistically significant association ( $\chi^2_{(4,128)}=9.290; p<.054$ ). Thus, the hypothesis H1f cannot be confirmed. However, in tendency projects of Type 3 can be most often implemented with the use of already existing infrastructure, followed by Type 2- and Type 1 projects. This means that Type 3 projects incur the lowest expenditures for specific infrastructure, relative to Type 2- and Type 1 projects.

Concerning the question if the knowledge needed for the implementation of projects is generally **explicit knowledge** (rather than tacit), the survey showed the following results presented in Table 22.

<b>Crosstab</b>						
			degree of explicit knowledge			Total
			Low	Middle	High	
project type	Type 1	Count	15	4	22	41
		Expected Count	11,2	5,6	24,3	41,0
		% within project type	36,6%	9,8%	53,7%	100,0%
		Std. Residual	1,2	-,7	-,5	
	Type 2	Count	9	11	22	42
		Expected Count	11,4	5,7	24,9	42,0
		% within project type	21,4%	26,2%	52,4%	100,0%
		Std. Residual	-,7	2,2	-,6	
	Type 3	Count	10	2	30	42
		Expected Count	11,4	5,7	24,9	42,0
		% within project type	23,8%	4,8%	71,4%	100,0%
		Std. Residual	-,4	-1,6	1,0	
Total	Count	34	17	74	125	
	Expected Count	34,0	17,0	74,0	125,0	
	% within project type	27,2%	13,6%	59,2%	100,0%	

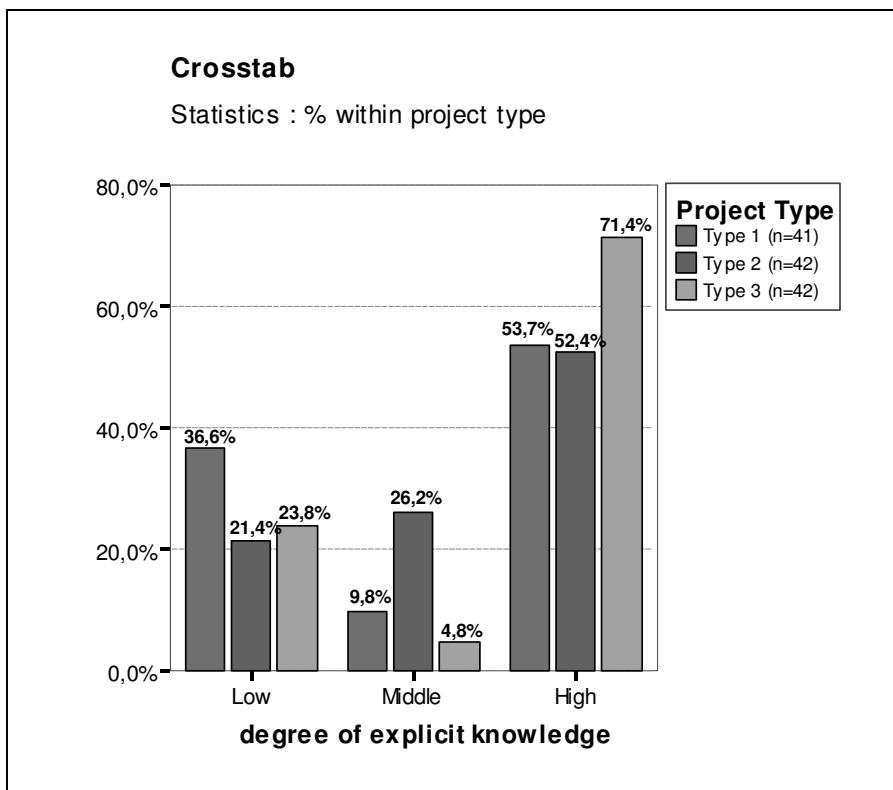
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11,376 <sup>a</sup>	4	,023
Likelihood Ratio	11,057	4	,026
Linear-by-Linear Association	2,523	1	,112
N of Valid Cases	125		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,58.

**Table 22: Crosstabulation – degree of explicit knowledge**

The analysis of the survey data showed that Type 1 projects are in 53.7% of the cases characterised by a high degree of explicit knowledge. For projects of Type 2 this was stated in 52.4% of the cases and for projects of Type 3 in 71.4% of the cases.

The corresponding frequency distribution is shown in Figure 35.



**Figure 35: Frequency distribution – degree of explicit knowledge**

The conducted chi-squared test indicates that there exist some project type-specific differences concerning the variable ‘degree of explicit knowledge’ ( $\chi^2_{(4,125)}=11.376; p<.023$ ). On average, projects of Type 3 are characterised by the highest level of explicit knowledge, relative to Type 2- and Type 1 projects. However, there is no clear difference between Type 1- and Type 2 projects. Thus, the hypothesis H1g cannot be confirmed.

On the basis of the presented survey results and hypothesis-tests, it can be summarised that the different R&D project types can be particularly differentiated by the following characteristics:

- degree of routine,
- degree of certainty, and
- potential for short-term commercialisation.

The statistical results confirmed that projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a higher degree of routine,
- a higher degree of certainty, and
- a higher potential for short-term commercialisation.

In the following section the project type-specific differences concerning the R&D organisation are investigated.

### 5.3 R&D organisation

As illustrated in the literature review (section 2.2) and the case study research (section 4.3), the implementation of the respective types of R&D projects takes place in different organisational arrangements. Since markets are characterised by decentralised structures, this section focuses on the analysis of the project type-specific R&D organisation. Therefore, the test of the following hypothesis has main emphasis:

H2: There are differences across R&D project types concerning the R&D organisation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by a higher degree of decentralisation concerning:

- a) the determination of R&D budgets,
- b) the project selection, and
- c) the implementation of projects.

In a first step, it was asked how the **determination of R&D budgets** is arranged from an organisational point of view.

The survey showed the following results presented in Table 23.

<b>Crosstab</b>						
			decentralised determination of budget			Total
			Low	Middle	High	
project type	Type 1	Count	29	10	5	44
		Expected Count	19,7	13,1	11,2	44,0
		% within project type	65,9%	22,7%	11,4%	100,0%
		Std. Residual	2,1	-,9	-1,8	
	Type 2	Count	18	15	12	45
		Expected Count	20,1	13,4	11,4	45,0
		% within project type	40,0%	33,3%	26,7%	100,0%
		Std. Residual	-,5	,4	,2	
	Type 3	Count	13	15	17	45
		Expected Count	20,1	13,4	11,4	45,0
		% within project type	28,9%	33,3%	37,8%	100,0%
		Std. Residual	-1,6	,4	1,7	
Total	Count	60	40	34	134	
	Expected Count	60,0	40,0	34,0	134,0	
	% within project type	44,8%	29,9%	25,4%	100,0%	

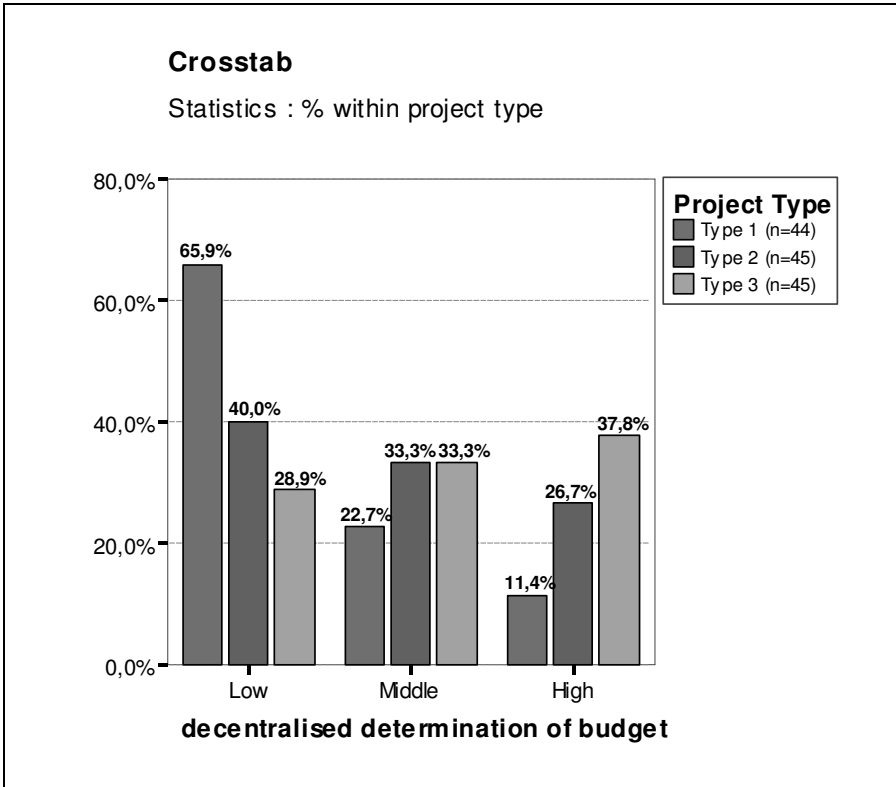
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14,430 <sup>a</sup>	4	,006
Likelihood Ratio	14,830	4	,005
Linear-by-Linear Association	13,355	1	,000
N of Valid Cases	134		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 11,16.

**Table 23: Crosstabulation – determination of budget**

The analysis of the survey data revealed that Type 1 projects were in 11.4% of the cases characterised by a high degree of decentralisation concerning the determination of budget. For Type 2 projects this was the case in 26.7% and for Type 3 projects in 37.8% of the observations.

The corresponding frequency distribution is shown in Figure 36.



**Figure 36: Frequency distribution – decentralised determination of budget**

Obviously there seems to be an association between the different project types and the degree of decentralisation concerning the determination of budget. This is also indicated by the conducted chi-squared test ( $\chi^2_{(4,134)}=14.430; p<.006$ ).

Relative to projects of Type 2 and particularly of Type 1, Type 3 projects are characterised by the highest degree of decentralisation concerning the determination of budget. Thus, the hypothesis H2a can be confirmed.

The survey results concerning the question how the **project selection** is organised are shown in Table 24.

<b>Crosstab</b>						
			decentralised project selection			Total
			Low	Middle	High	
project type	Type 1	Count	20	10	14	44
		Expected Count	12,5	9,2	22,3	44,0
		% within project type	45,5%	22,7%	31,8%	100,0%
		Std. Residual	2,1	,3	-1,8	
	Type 2	Count	11	11	23	45
		Expected Count	12,8	9,4	22,8	45,0
		% within project type	24,4%	24,4%	51,1%	100,0%
		Std. Residual	-,5	,5	,0	
	Type 3	Count	7	7	31	45
		Expected Count	12,8	9,4	22,8	45,0
		% within project type	15,6%	15,6%	68,9%	100,0%
		Std. Residual	-1,6	-,8	1,7	
Total	Count	38	28	68	134	
	Expected Count	38,0	28,0	68,0	134,0	
	% within project type	28,4%	20,9%	50,7%	100,0%	

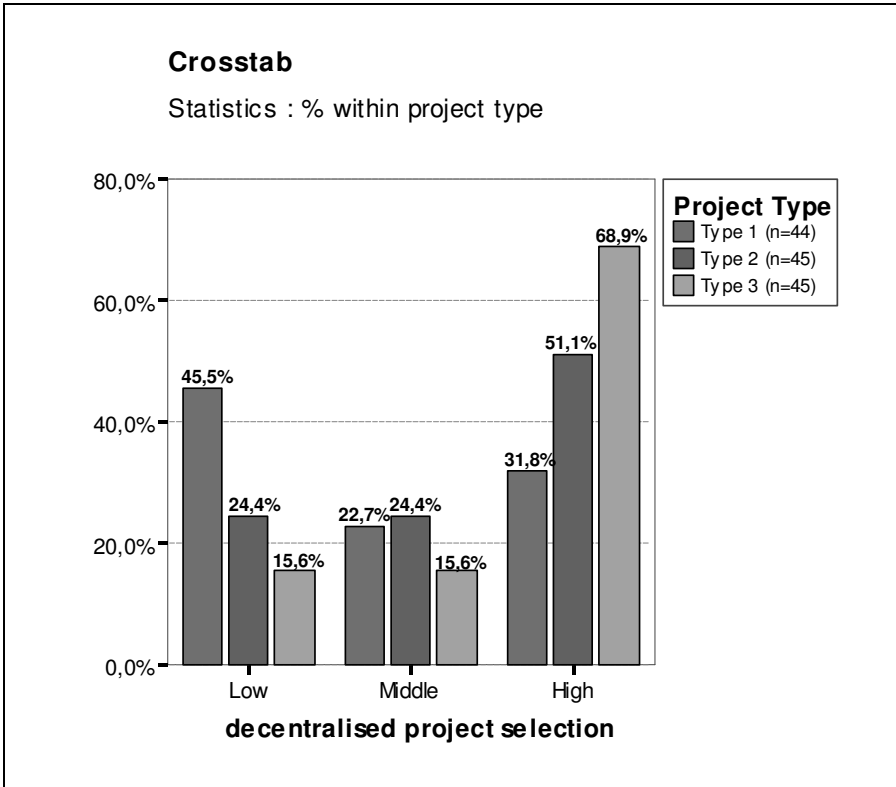
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14,361 <sup>a</sup>	4	,006
Likelihood Ratio	14,407	4	,006
Linear-by-Linear Association	13,346	1	,000
N of Valid Cases	134		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 9,19.

**Table 24: Crosstabulation – project selection**

The data from the survey showed that Type 1 projects are in 31.8% of the cases characterised by a high degree of decentralisation concerning the project selection. For projects of Type 2 this was valid in 51.1% of the cases and for projects of Type 3 in 68.9% of the cases.

The corresponding frequency distribution is shown in Figure 37.



**Figure 37: Frequency distribution – decentralised project selection**

The conducted chi-squared test indicates significant project type-specific differences with regard to the degree of decentralisation concerning the project selection ( $\chi^2_{(4,134)}=14.361; p<.006$ ). Projects of Type 3 are characterised by the highest degree of decentralisation concerning the project selection, followed by Type 2- and Type 1 projects. On this basis the hypothesis H2b can be confirmed.

With regard to the **implementation of projects**, it was asked to what extent the different project types are carried out decentrally, i.e. in the divisions/business units. The corresponding results are shown in Table 25.

<b>Crosstab</b>						
			decentralised implementation of projects			Total
			Low	Middle	High	
project type	Type 1	Count	28	6	10	44
		Expected Count	17,2	5,5	21,3	44,0
		% within project type	63,6%	13,6%	22,7%	100,0%
		Std. Residual	2,6	,2	-2,5	
	Type 2	Count	14	5	23	42
		Expected Count	16,4	5,3	20,3	42,0
		% within project type	33,3%	11,9%	54,8%	100,0%
		Std. Residual	-,6	-,1	,6	
	Type 3	Count	8	5	29	42
		Expected Count	16,4	5,3	20,3	42,0
		% within project type	19,0%	11,9%	69,0%	100,0%
		Std. Residual	-2,1	-,1	1,9	
Total	Count	50	16	62	128	
	Expected Count	50,0	16,0	62,0	128,0	
	% within project type	39,1%	12,5%	48,4%	100,0%	

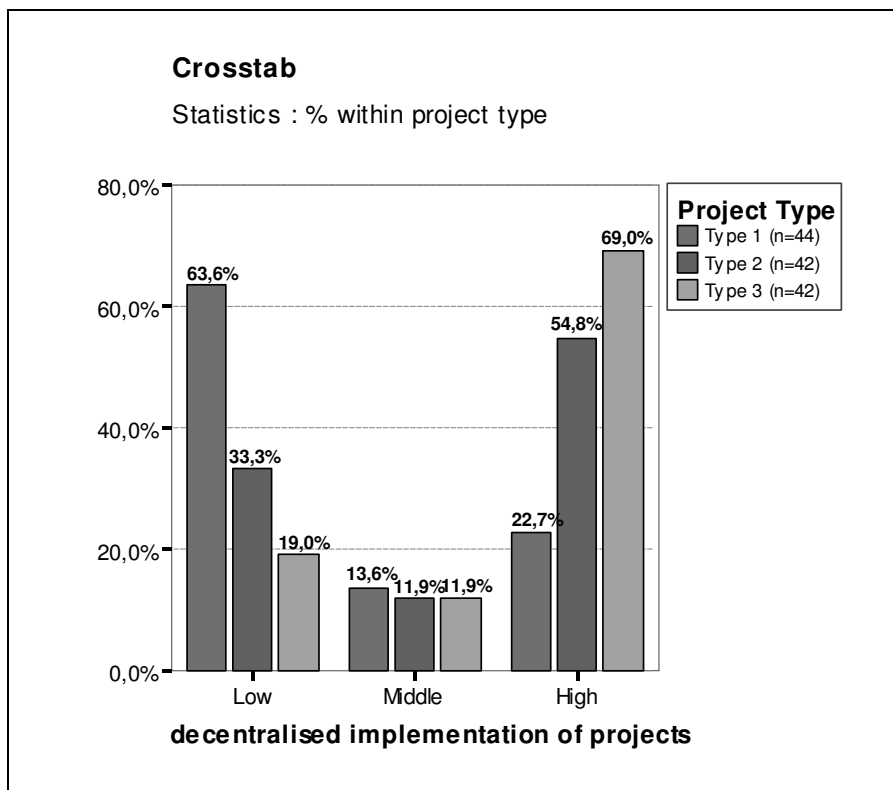
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21,566 <sup>a</sup>	4	,000
Likelihood Ratio	22,538	4	,000
Linear-by-Linear Association	20,461	1	,000
N of Valid Cases	128		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,25.

**Table 25: Crosstabulation – decentralised implementation of projects**

The respondents stated that Type 1 projects are in 22.7% of the cases characterised by a high degree of decentralisation concerning the implementation of projects. For Type 2 projects this answer was given in 54.8% of the cases and for Type 3 projects in 69.0% of the cases.

The corresponding frequency distribution is shown in Figure 38.



**Figure 38: Frequency distribution – decentralised implementation of projects**

It can be stated that Type 3 projects are characterised by the highest degree of decentralisation concerning the implementation of projects, followed by projects of Type 2 and Type 1. This association is also indicated by the conducted chi-squared test ( $\chi^2_{(4,128)}=21.566$ ;  $p<.000$ ). Thus, the hypothesis H2c can be confirmed.

On the basis of the presented survey results and hypothesis-tests, it can be summarised that there exist project type-specific differences with regard to the degree of decentralisation concerning:

- the determination of R&D budgets,
- the project selection, and
- the implementation of projects.

The statistical results confirmed that projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a higher degree of decentralisation concerning the determination of R&D budgets,
- a higher degree of decentralisation concerning the project selection, and
- a higher degree of decentralisation concerning the implementation of projects.

In the following section the project type-specific differences concerning the R&D resource allocation are investigated.

## 5.4 R&D resource allocation

The two previous sections dealt with the different characteristics of R&D project types and the project type-specific R&D organisation. In this section the empirical findings concerning the R&D resource allocation, respectively, the different forms of resource allocation are presented. Essentially, it is about answering the question if the resource allocation takes place project type-specifically; this means if different forms of resource allocation are applied for the investigated project types.

The following statistical data analysis is concerned with the characteristics of a market-driven allocation of resources. The survey illustrates that the R&D resource allocation still has a rather hierarchical character in many companies. This is getting obvious by the fact that in many companies – independent of the project type (Type 1 = 46.5%; Type 2 = 40.9%; Type 3 = 45.5%) – the part of the budget that is determined by the interaction of supply and demand is very low (0%-20%). This confirms that market-driven forms of resource allocation are still not an established standard in the R&D field.

To provide the reader a realistic picture on how market-driven resource allocation is organised all the cases in which the resource allocation is mainly based on hierarchical mechanisms had to be excluded. Thus, the following analysis comprises only a subset of cases in which the interaction of supply and demand determines at least 20 percent of the respective R&D budget. Based on the findings presented below the following hypothesis is tested:

H3: There are differences across R&D project types concerning the application of market-driven forms of resource allocation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a) a stronger interaction of supply and demand,
- b) a higher share of projects that is initiated by the demand side, and
- c) a higher financing share of the requesting divisions/business units.

Firstly, it was asked which percentage of the R&D budget is determined by the **interaction of supply and demand**, without interference of a central committee.

Concerning this aspect, the survey showed the following results (see Table 26).

<b>Crosstab</b>						
			interaction of supply and demand			Total
			Low	Middle	High	
project type	Type 1	Count	7	3	13	23
		Expected Count	2,5	3,5	17,0	23,0
		% within project type	30,4%	13,0%	56,5%	100,0%
		Std. Residual	2,8	-,3	-1,0	
	Type 2	Count	1	6	19	26
		Expected Count	2,8	3,9	19,2	26,0
		% within project type	3,8%	23,1%	73,1%	100,0%
		Std. Residual	-1,1	1,1	-,1	
	Type 3	Count	0	2	22	24
		Expected Count	2,6	3,6	17,8	24,0
		% within project type	,0%	8,3%	91,7%	100,0%
		Std. Residual	-1,6	-,8	1,0	
Total	Count	8	11	54	73	
	Expected Count	8,0	11,0	54,0	73,0	
	% within project type	11,0%	15,1%	74,0%	100,0%	

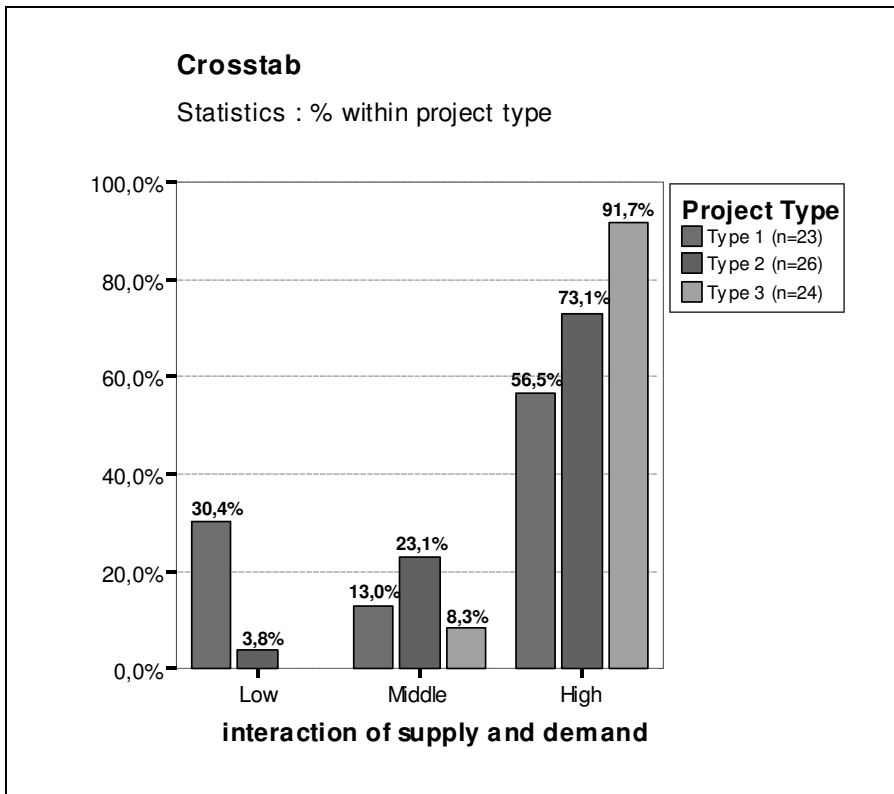
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15,648 <sup>a</sup>	4	,004
Likelihood Ratio	16,063	4	,003
Linear-by-Linear Association	10,965	1	,001
N of Valid Cases	73		

a. 6 cells (66,7%) have expected count less than 5. The minimum expected count is 2,52.

**Table 26: Crosstabulation – interaction of supply and demand**

As mentioned above, the presented analysis comprises only those cases in which the interaction of supply and demand determines at least 20 percent of the respective R&D budget. The corresponding data from the survey showed that Type 1 projects are in 56.5% of the cases characterised by a high interaction of supply and demand. This means that the share of the budget which is determined by the direct interaction of supply and demand amounts to 60% or more. For projects of Type 2 this is valid in 73.1% of the cases and for projects of Type 3 in 91.7% of the cases.

The corresponding frequency distribution is shown in Figure 39.



**Figure 39: Frequency distribution – interaction of supply and demand**

The survey results show project type-specific differences concerning the impact of the project type on the applied form of resource allocation. This is also underpinned by the conducted chi-squared test ( $\chi^2_{(4,73)}=15.648; p<.004$ ). Within the scope of the determination of the R&D budgets the direct interaction of supply and demand can be found most often by Type 3 projects, followed by Type 2 projects and Type 1 projects. Thus, the hypothesis H3a can be confirmed.

As discussed in the conceptual framework (section 3.2), the direct interaction of supply and demand is a major characteristic of market-driven forms of resource allocation.

Additionally, the survey dealt with the question, by whom the respective projects are initiated. In market-like solutions R&D projects are usually initiated by the requesting divisions and/or business units (refer to section 3.2).

The corresponding **share of projects that is initiated by the demand side** (divisions/business units) is presented in Table 27.

Crosstab						
			share of projects that is initiated by the demand side			Total
			Low	Middle	High	
project type	Type 1	Count	14	4	3	21
		Expected Count	6,6	5,0	9,4	21,0
		% within project type	66,7%	19,0%	14,3%	100,0%
		Std. Residual	2,9	-,5	-2,1	
	Type 2	Count	5	8	11	24
		Expected Count	7,5	5,7	10,7	24,0
		% within project type	20,8%	33,3%	45,8%	100,0%
		Std. Residual	-,9	,9	,1	
	Type 3	Count	2	4	16	22
		Expected Count	6,9	5,3	9,9	22,0
		% within project type	9,1%	18,2%	72,7%	100,0%
		Std. Residual	-1,9	-,5	2,0	
Total	Count	21	16	30	67	
	Expected Count	21,0	16,0	30,0	67,0	
	% within project type	31,3%	23,9%	44,8%	100,0%	

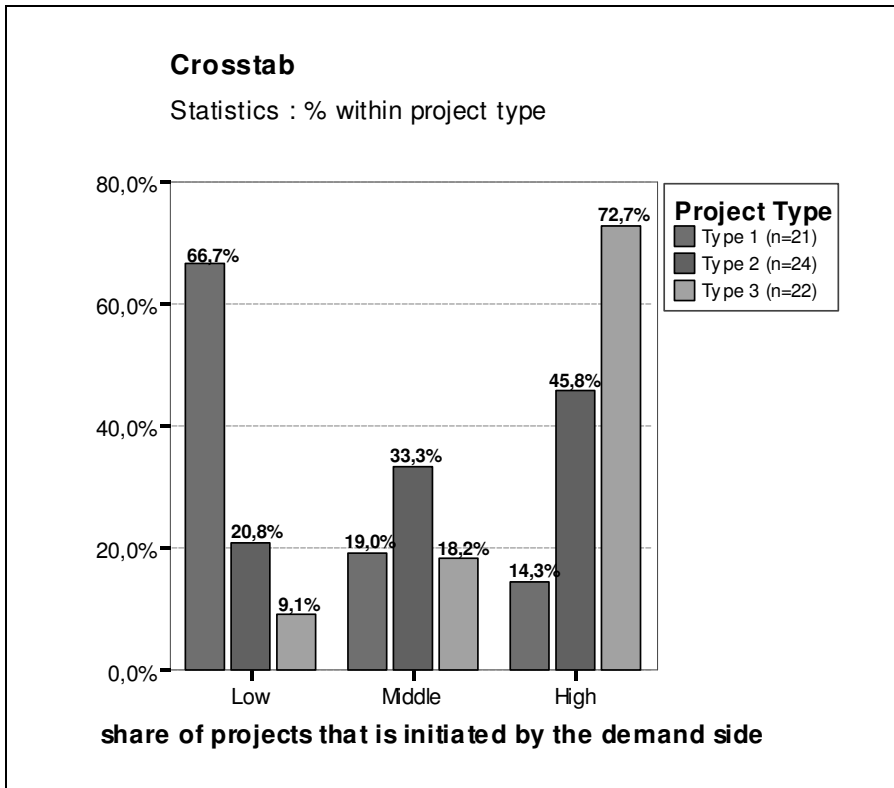
Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22,289 <sup>a</sup>	4	,000
Likelihood Ratio	22,622	4	,000
Linear-by-Linear Association	19,067	1	,000
N of Valid Cases	67		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,01.

**Table 27: Crosstabulation – share of projects that is initiated by the demand side**

The analysis of the survey data revealed that Type 1 projects were in 14.3% of the cases characterised by a high share of projects (>60%) that is initiated by the demand side. For Type 2 projects this was the case in 45.8% and for Type 3 projects in 72.7% of the relevant observations.

The corresponding frequency distribution is shown in Figure 40.



**Figure 40: Frequency distribution – share of projects that is initiated by the demand side**

The frequency distribution illustrates that the share of projects that is initiated by the demand side is the highest for Type 3 projects, followed by projects of Type 2 and Type 1. This association is also indicated by the significant result of the chi-squared test ( $\chi^2_{(4,67)}=22.289; p<.000$ ). On the basis of these insights the hypothesis H3b can be confirmed.

Furthermore, it was asked by whom the respective R&D budgets are financed. As illustrated in the conceptual framework (section 3.2), market-driven forms of resource allocation are characterised by the fact that the requesting divisions and/or business units have to pay a price for the R&D activities done on their behalf.

The **financing share of requesting divisions and/or business units** is shown in Table 28.

Crosstab						
			financing share of requesting divisions/business units			Total
			Low	Middle	High	
project type	Type 1	Count	8	4	11	23
		Expected Count	4,1	2,2	16,7	23,0
		% within project type	34,8%	17,4%	47,8%	100,0%
		Std. Residual	1,9	1,2	-1,4	
	Type 2	Count	5	1	20	26
		Expected Count	4,6	2,5	18,9	26,0
		% within project type	19,2%	3,8%	76,9%	100,0%
		Std. Residual	,2	-,9	,3	
	Type 3	Count	0	2	22	24
		Expected Count	4,3	2,3	17,4	24,0
		% within project type	,0%	8,3%	91,7%	100,0%
		Std. Residual	-2,1	-,2	1,1	
Total	Count	13	7	53	73	
	Expected Count	13,0	7,0	53,0	73,0	
	% within project type	17,8%	9,6%	72,6%	100,0%	

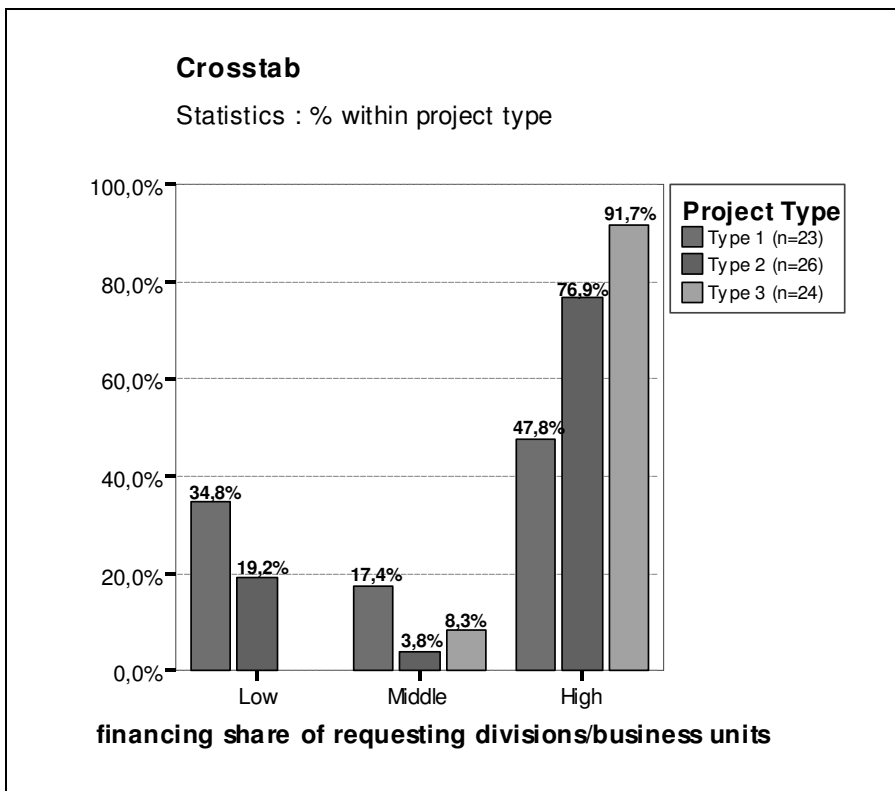
Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13,632 <sup>a</sup>	4	,009
Likelihood Ratio	17,242	4	,002
Linear-by-Linear Association	11,836	1	,001
N of Valid Cases	73		

a. 6 cells (66,7%) have expected count less than 5. The minimum expected count is 2,21.

**Table 28: Crosstabulation – financing share of requesting divisions/business units**

The respondents stated that Type 1 projects are in 47.8% of the relevant cases characterised by a high financing share (>60%) of requesting divisions and/or business units. For Type 2 projects this answer was given in 76.9% of the cases and for Type 3 projects in 91.7% of the cases.

The corresponding frequency distribution is shown in Figure 41.



**Figure 41: Frequency distribution – financing share of requesting divisions / business units**

The results show that the financing share of the requesting divisions/business units is the highest for Type 3 projects, followed by projects of Type 2 and Type 1. This association is also indicated by the conducted chi-squared test ( $\chi^2_{(4,73)}=13.632; p<.009$ ). Therefore, the hypothesis H3c can be confirmed.

On the basis of the presented survey results and hypothesis-tests, it can be summarised that there exist project type-specific differences concerning the R&D resource allocation. Specifically, the study revealed project type-specific differences concerning:

- the interaction of supply and demand,
- the share of projects that is initiated by the demand side, and
- the financing share of the requesting divisions/business units.

The statistical results confirmed that projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a stronger interaction of supply and demand,
- a higher share of projects that is initiated by the demand side, and
- a higher financing share of the requesting divisions/business units.

In the following section the project type-specific differences concerning the allocation result are investigated.

## 5.5 Allocation result

This section, finally, investigates how the respondents evaluated the effectiveness (doing the right things) and the efficiency (doing things right) of market-driven forms of resource allocation.

It was asked if through the application of market-driven forms of resource allocation (direct assignments) the most lucrative projects are selected (effectiveness). Furthermore, it was asked if market-driven forms of resource allocation, in comparison with hierarchical forms of resource allocation, lead to a more efficient allocation in terms of quality, time and costs.

Both, the insights of the case studies and the findings of the survey showed that market-driven forms of resource allocation are most often applied for Type 3 projects, followed by Type 2- and Type 1 projects. This distinct treatment of the respective project types should also be reflected in the survey results concerning the evaluation of the effectiveness and efficiency of market-driven forms of resource allocation. Thus, the remainder of this section focuses on the estimates of the companies concerning the favourability of market-driven forms of resource allocation in contrast to hierarchical forms of resource allocation. In this context the following hypothesis is tested:

H4: There are differences across R&D project types concerning the effectiveness and/or efficiency of market-driven forms of resource allocation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a) a higher effectiveness of direct assignments,
- b) a higher efficiency in terms of an improved adaptability (quality),
- c) a higher efficiency in terms of a shorter resource allocation process (time), and
- d) a higher efficiency in terms of lower costs.

First of all the **effectiveness of direct assignments** was investigated. It was asked if direct assignments of divisions and/or business units lead to a better achievement of objectives (more effective selection), in comparison with projects predetermined by committees.

Concerning this aspect, the survey showed the following results (see Table 29):

<b>Crosstab</b>						
		effectiveness of direct assignments			Total	
		Low	Middle	High		
project type	Type 1	Count	12	11	21	44
		Expected Count	6,7	9,0	28,3	44,0
		% within project type	27,3%	25,0%	47,7%	100,0%
		Std. Residual	2,1	,7	-1,4	
	Type 2	Count	5	9	30	44
		Expected Count	6,7	9,0	28,3	44,0
		% within project type	11,4%	20,5%	68,2%	100,0%
		Std. Residual	-,6	,0	,3	
	Type 3	Count	3	7	34	44
		Expected Count	6,7	9,0	28,3	44,0
		% within project type	6,8%	15,9%	77,3%	100,0%
		Std. Residual	-1,4	-,7	1,1	
Total	Count	20	27	85	132	
	Expected Count	20,0	27,0	85,0	132,0	
	% within project type	15,2%	20,5%	64,4%	100,0%	

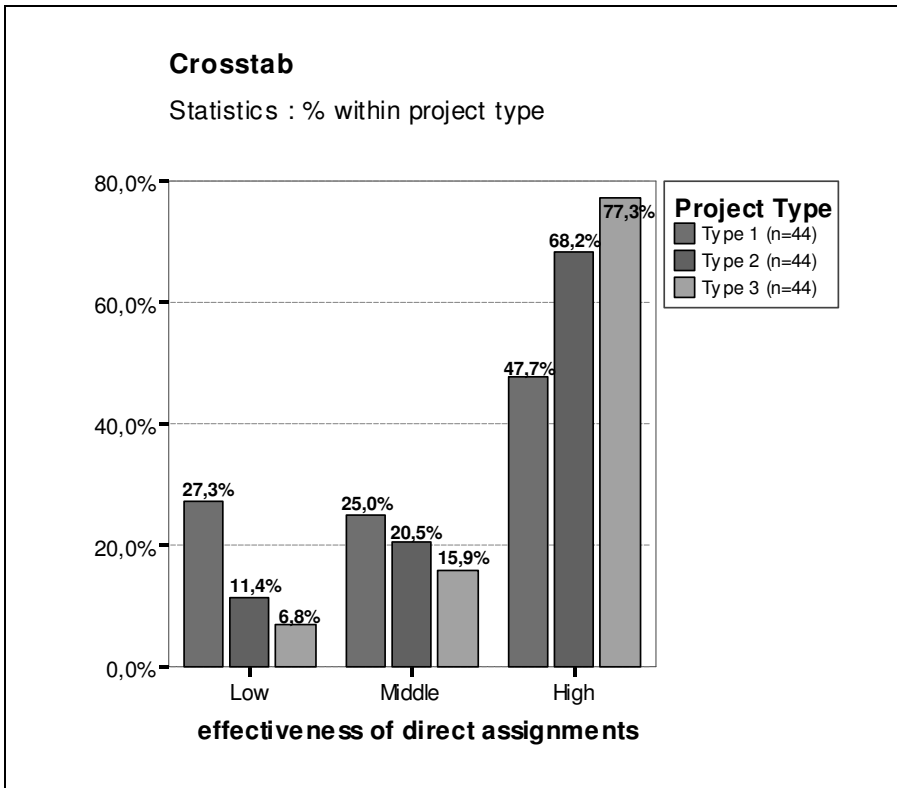
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10,718 <sup>a</sup>	4	,030
Likelihood Ratio	10,583	4	,032
Linear-by-Linear Association	9,871	1	,002
N of Valid Cases	132		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 6,67.

**Table 29: Crosstabulation – effectiveness of direct assignments**

The survey participants stated in 47.7% of the cases that the effectiveness of direct assignments for Type 1 projects is high. For projects of Type 2 this was stated in 68.2% and for projects of Type 3 in 77.3% of the cases.

The corresponding frequency distribution is shown in Figure 42.



**Figure 42: Frequency distribution – effectiveness of direct assignments**

In general, market-driven forms of resource allocation, in form of direct assignments of the requesting divisions/business units, were considered as being more effective than the project selection via hierarchical decision-committees.

This was most often the case for projects of Type 3, followed by projects of Type 2 and Type 1. These project type-specific differences are also indicated by the conducted chi-squared test ( $\chi^2_{(4,132)}=10.718; p<.030$ ). Thus, the hypothesis H4a can be confirmed.

Furthermore, a set of efficiency criteria was analysed (quality, time, costs). Concerning the question if the allocation of project resources by supply and demand leads to an **improved adaptability** to changes in the environment, and thereby to a more flexible resource control (e.g. reaction to changed customer needs), the survey showed the following results (see Table 30).

<b>Crosstab</b>						
			efficiency in terms of an improved adaptability			Total
			Low	Middle	High	
project type	Type 1	Count	14	12	17	43
		Expected Count	8,5	10,2	24,4	43,0
		% within project type	32,6%	27,9%	39,5%	100,0%
		Std. Residual	1,9	,6	-1,5	
	Type 2	Count	5	11	26	42
		Expected Count	8,3	9,9	23,8	42,0
		% within project type	11,9%	26,2%	61,9%	100,0%
		Std. Residual	-1,1	,3	,4	
	Type 3	Count	6	7	29	42
		Expected Count	8,3	9,9	23,8	42,0
		% within project type	14,3%	16,7%	69,0%	100,0%
		Std. Residual	-,8	-,9	1,1	
Total	Count	25	30	72	127	
	Expected Count	25,0	30,0	72,0	127,0	
	% within project type	19,7%	23,6%	56,7%	100,0%	

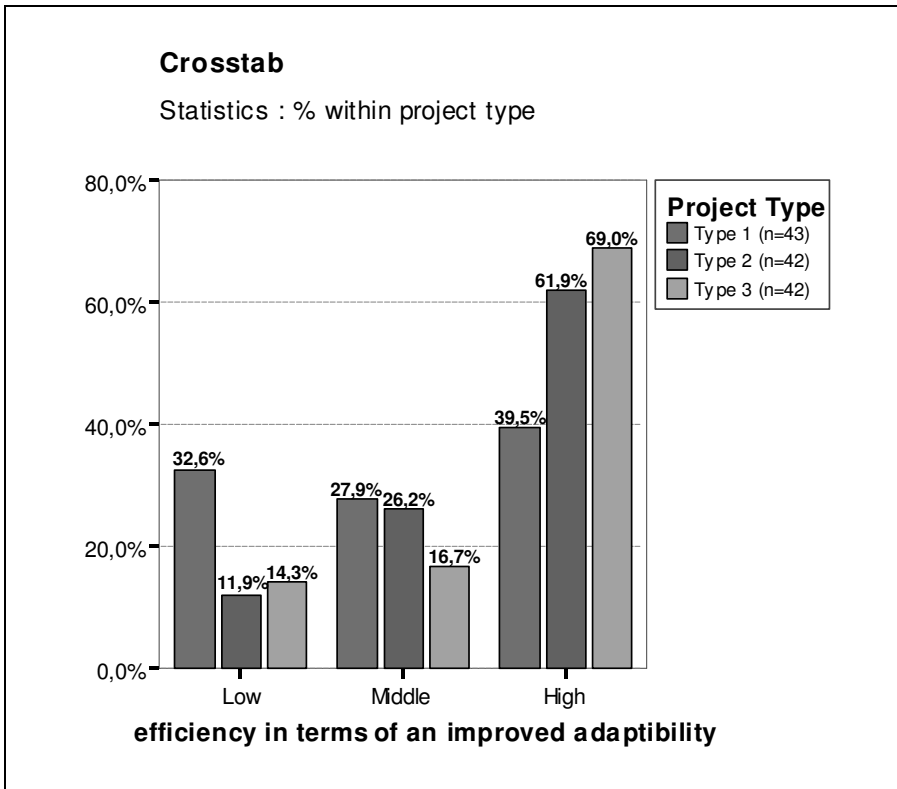
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10,410 <sup>a</sup>	4	,034
Likelihood Ratio	10,353	4	,035
Linear-by-Linear Association	7,727	1	,005
N of Valid Cases	127		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 8,27.

**Table 30: Crosstabulation – efficiency in terms of an improved adaptability**

Concerning this quality aspect, the survey data showed that the efficiency of market-driven forms of resource allocation for Type 1 projects is in 39.5% of the cases high. For projects of Type 2 this was stated in 61.9% and for projects of Type 3 in 69.0% of the cases.

The corresponding frequency distribution is shown in Figure 43.



**Figure 43: Frequency distribution – efficiency in terms of an improved adaptability**

The conducted chi-squared test indicates significant project type-specific differences concerning this variable ( $\chi^2_{(4,127)}=10.410; p<.034$ ). The estimates showed that market-driven forms of resource allocation most often lead to an improved adaptability and thus to a more flexible resource allocation for Type 3 projects, followed by projects of Type 2 and Type 1. On this basis the hypothesis H4b can be confirmed.

Concerning the question if the allocation of project resources by supply and demand leads to a **shorter resource allocation process** (from the filing of application until the distribution of funds), the survey showed the following results (see Table 31).

<b>Crosstab</b>						
			efficiency in terms of a shorter resource allocation process			Total
			Low	Middle	High	
project type	Type 1	Count	14	15	13	42
		Expected Count	11,2	15,2	15,6	42,0
		% within project type	33,3%	35,7%	31,0%	100,0%
		Std. Residual	,8	-,1	-,7	
	Type 2	Count	10	16	15	41
		Expected Count	10,9	14,9	15,2	41,0
		% within project type	24,4%	39,0%	36,6%	100,0%
		Std. Residual	-,3	,3	-,1	
	Type 3	Count	9	14	18	41
		Expected Count	10,9	14,9	15,2	41,0
		% within project type	22,0%	34,1%	43,9%	100,0%
		Std. Residual	-,6	-,2	,7	
Total	Count	33	45	46	124	
	Expected Count	33,0	45,0	46,0	124,0	
	% within project type	26,6%	36,3%	37,1%	100,0%	

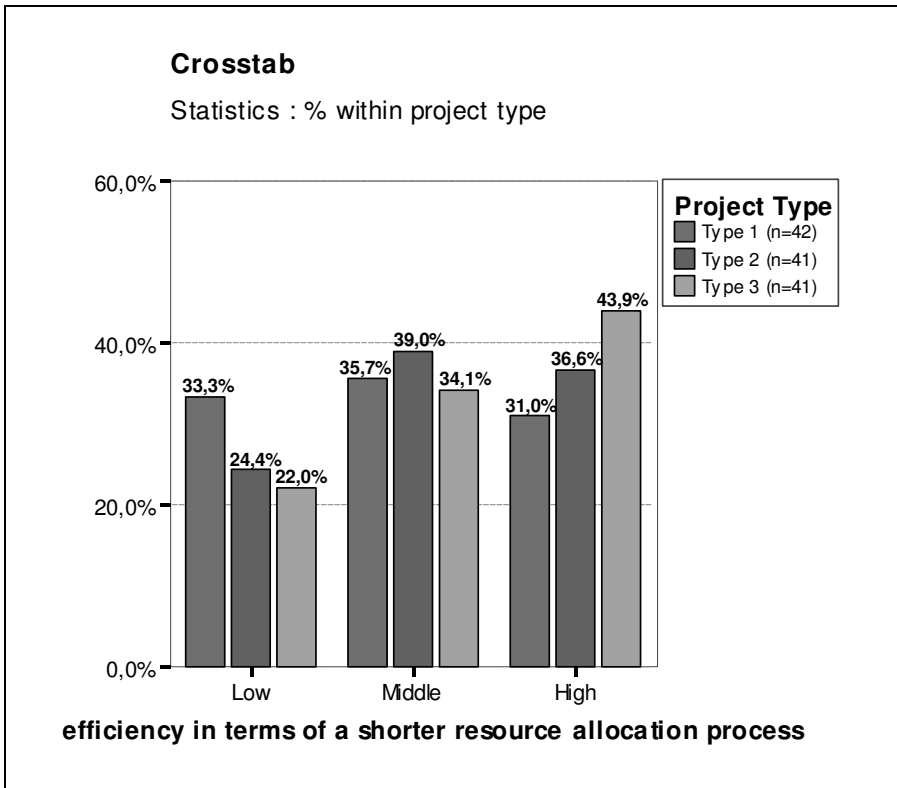
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2,206 <sup>a</sup>	4	,698
Likelihood Ratio	2,173	4	,704
Linear-by-Linear Association	1,949	1	,163
N of Valid Cases	124		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 10,91.

**Table 31: Crosstabulation – efficiency in terms of a shorter resource allocation process**

Concerning this time aspect, the respondents stated that the efficiency of market-driven forms of resource allocation for Type 1 projects is in 31.0% of the cases high. For projects of Type 2 this was stated in 36.6% and for projects of Type 3 in 43.9% of the cases.

The corresponding frequency distribution is shown in Figure 44.



**Figure 44: Frequency distribution – efficiency in terms of a shorter resource allocation process**

Figure 44 shows only slight project type-specific differences concerning the efficiency of market-driven forms of resource allocation in terms of a shorter resource allocation process. Consequently, the conducted chi-squared test presented the following non-significant result: ( $\chi^2_{(4,124)}=2.206; p<.698$ ). On this basis the hypothesis H4c cannot be confirmed.

As pointed out in the theoretical underpinnings of the work (refer to section 2.4), transaction costs can be subdivided into coordination costs on the one hand and motivation costs on the other hand.

In a first step, it was asked if the allocation of project resources by supply and demand leads to **lower coordination costs**. The corresponding survey results are shown in Table 32.

<b>Crosstab</b>						
			efficiency in terms of lower coordination costs			Total
			Low	Middle	High	
project type	Type 1	Count	17	10	15	42
		Expected Count	16,0	10,3	15,7	42,0
		% within project type	40,5%	23,8%	35,7%	100,0%
		Std. Residual	,3	-,1	-,2	
	Type 2	Count	16	10	16	42
		Expected Count	16,0	10,3	15,7	42,0
		% within project type	38,1%	23,8%	38,1%	100,0%
		Std. Residual	,0	-,1	,1	
	Type 3	Count	15	11	16	42
		Expected Count	16,0	10,3	15,7	42,0
		% within project type	35,7%	26,2%	38,1%	100,0%
		Std. Residual	-,3	,2	,1	
Total	Count	48	31	47	126	
	Expected Count	48,0	31,0	47,0	126,0	
	% within project type	38,1%	24,6%	37,3%	100,0%	

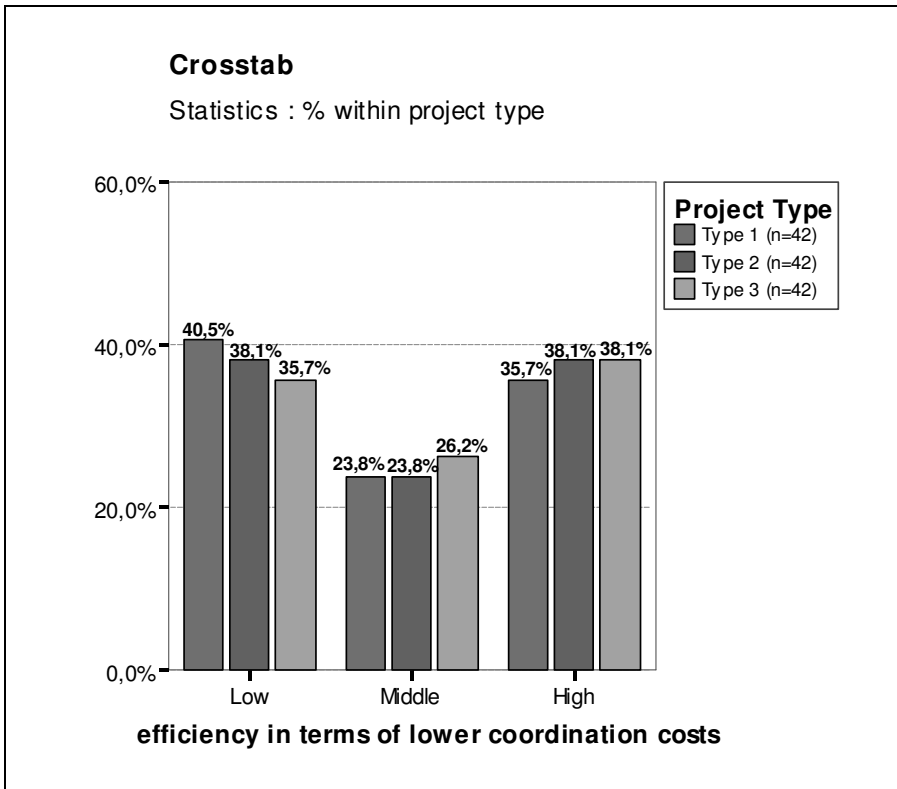
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	,232 <sup>a</sup>	4	,994
Likelihood Ratio	,232	4	,994
Linear-by-Linear Association	,141	1	,707
N of Valid Cases	126		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 10,33.

**Table 32: Crosstabulation – efficiency in terms of lower coordination costs**

Concerning the coordination costs, the survey participants stated that the efficiency of market-driven forms of resource allocation for Type 1 projects is in 35.7% of the cases high. For projects of Type 2 and Type 3 this was stated in 38.1% of the cases.

The corresponding frequency distribution is shown in Figure 45.



**Figure 45: Frequency distribution – efficiency in terms of lower coordination costs**

It is shown that market-driven and hierarchical forms of resource allocation were judged as being almost equally efficient with regard to the associated coordination costs. The estimates of the polled experts showed almost no project type-specific differences concerning this issue. This is also documented by the results of the chi-squared test ( $\chi^2_{(4,126)}=.232; p<.994$ ).

In a second step, it was asked if the allocation of project resources by supply and demand leads to lower **motivation costs**.

The corresponding results of the survey are presented in Table 33.

<b>Crosstab</b>						
			efficiency in terms of lower motivation costs			Total
			Low	Middle	High	
project type	Type 1	Count	18	12	10	40
		Expected Count	16,0	12,7	11,3	40,0
		% within project type	45,0%	30,0%	25,0%	100,0%
		Std. Residual	,5	-,2	-,4	
	Type 2	Count	15	13	12	40
		Expected Count	16,0	12,7	11,3	40,0
		% within project type	37,5%	32,5%	30,0%	100,0%
		Std. Residual	-,3	,1	,2	
	Type 3	Count	15	13	12	40
		Expected Count	16,0	12,7	11,3	40,0
		% within project type	37,5%	32,5%	30,0%	100,0%
		Std. Residual	-,3	,1	,2	
Total	Count	48	38	34	120	
	Expected Count	48,0	38,0	34,0	120,0	
	% within project type	40,0%	31,7%	28,3%	100,0%	

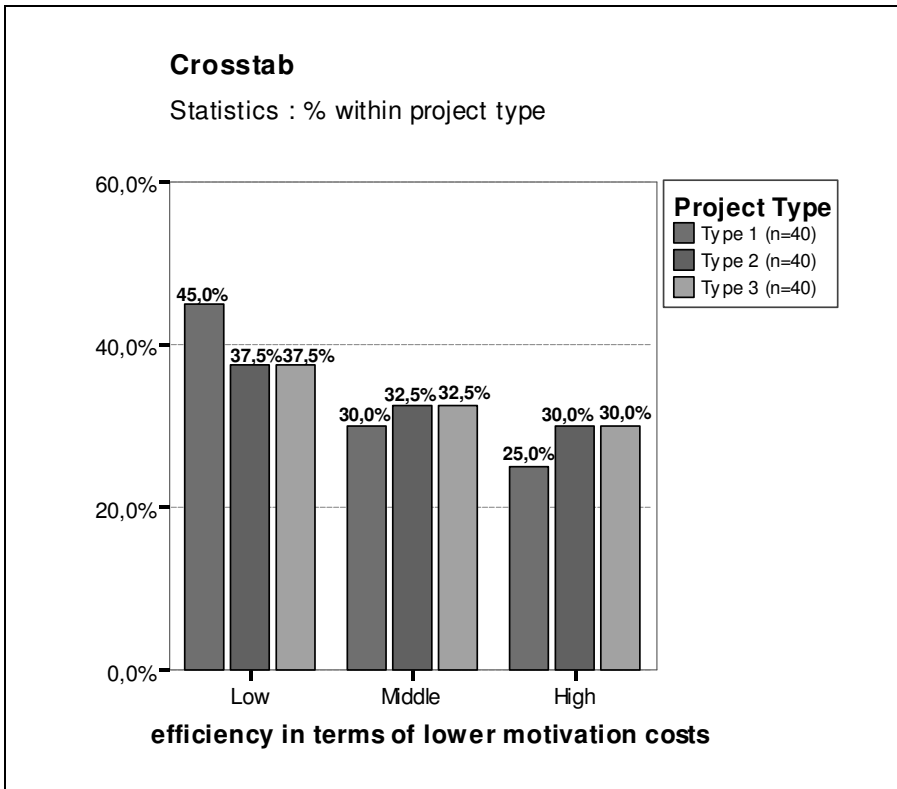
<b>Chi-Square Tests</b>			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	,663 <sup>a</sup>	4	,956
Likelihood Ratio	,661	4	,956
Linear-by-Linear Association	,463	1	,496
N of Valid Cases	120		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 11,33.

**Table 33: Crosstabulation – efficiency in terms of lower motivation costs**

With regard to the motivation costs, the respondents stated that the efficiency of market-driven forms of resource allocation for Type 1 projects is in 25.0% of the cases high. For projects of Type 2 and Type 3 this was stated in 30.0% of the cases.

The corresponding frequency distribution is shown in Figure 46.



**Figure 46: Frequency distribution – efficiency in terms of lower motivation costs**

The conducted chi-squared test indicates no project type-specific differences concerning the efficiency of market-driven forms of resource allocation in terms of lower motivation costs ( $\chi^2_{(4,120)}=.663; p<.956$ ). In tendency, the estimates concerning this aspect were slightly in favour of hierarchical forms of resource allocation.

Based on the findings concerning the coordination costs on the one hand and the motivation costs on the other hand the hypothesis H4d cannot be confirmed.

On the basis of the presented survey results and hypothesis-tests, it can be summarised that there exist project type-specific differences concerning the allocation result. Specifically, the survey revealed project type-specific differences concerning:

- the effectiveness of direct assignments, and
- the efficiency in terms of an improved adaptability.

The statistical results confirmed that there are differences across R&D project types concerning the effectiveness and efficiency of market-driven forms of resource allocation. Projects of Type 3 are compared to projects of Type 2 and particularly to projects of Type 1 characterised by:

- a higher effectiveness of direct assignments, and
- a higher efficiency in terms of an improved adaptability.

In the following section the findings of the survey are summarised and discussed.

## **5.6 Summary and discussion of results**

The major research intention of the inquiry was the investigation of project type-specific differences concerning the characteristics of R&D project types, the R&D organisation, the R&D resource allocation, and the allocation result. Therefore, a project typology was created on the basis of already existing project typologies (see section 2.1) and the results of the case study research (see section 4.2). This newly developed project typology served as the basis for the design of a questionnaire and for hypothesis-testing. On this basis it should be investigated for which types of R&D projects a market-driven allocation of resources is (a) possible and (b) more effective and/or efficient than hierarchical forms of resource allocation.

In the following the main survey results, which were presented in the previous sections, are summarised and discussed:

### **Characteristics of R&D project types**

In a first step, the project type-specific differences concerning the project characteristics were analysed. In summary it may be said that the investigated R&D project types can be mainly differentiated on the basis of the characteristics 'degree of routine,' 'degree of certainty,' and 'time-to-market'.

The analysis revealed that Type 3 projects are compared to Type 2- and particularly Type 1 projects characterised by a higher degree of routine, a higher degree of certainty and a higher potential for short-term commercialisation. Vice versa Type 1 projects are compared to Type 2- and particularly Type 3 projects characterised by a higher degree of innovation, a higher degree of uncertainty and a higher time-to-market.

Based on the survey results it can be concluded that these three characteristics are most suitable for the categorisation of R&D projects. Furthermore, these characteristics play an important role for the discussion of results in the remainder of this section.

### **R&D organisation**

In a second step, the analysis was concerned with the project type-specific differences concerning the R&D organisation. The results showed that Type 2 projects and particularly Type 3 projects are characterised by a relatively high degree of decentralisation, whereas Type 1 projects are characterised by a relatively high degree of centralisation.

This organisational separation makes clear that there are two main interfaces for market-like exchanges within a company: On the one hand between the decentralised units (divisions, business units, development units etc.) and the centralised R&T units and on the other hand between the units that are close to markets (divisions, business units, marketing companies etc.) and the R&D units. At these two main interfaces the respective market participants can settle their reciprocal orders.

As illustrated in the conceptual framework (see section 3.2), a main prerequisite for market-driven internal allocation processes is the decision autonomy of the involved parties. Thus, it can be argued that the high degree of centralisation in tendency impedes the application of market-driven forms of resource allocation for Type 1 projects.

For projects of Type 2 and Type 3, however, the conditions for a market-driven allocation are better. This is because of the higher degree of decentralisation concerning the determination of budget, the project selection and the implementation of projects.

The impact of these project type-specific organisational differences on the application of market-driven forms of resource allocation is also discussed in the remainder of this section.

### **R&D resource allocation**

In a third step, it was focused on the project type-specific differences concerning the R&D resource allocation. First of all it was proved that market-driven forms of resource allocation are not an established standard in R&D contexts.

However, the analysis revealed the following significant project type-specific differences: It was shown that depending on the project type different forms of resource allocation are applied. Type 3- and Type 2 projects are compared to Type 1 projects characterised by a higher share of budget which is determined by the interaction of supply and demand, a higher share of projects that is initiated by the demand side, and a higher financing share of the requesting divisions and/or business units.

In summary it may be said that market-driven forms of resource allocation are most often applied for Type 3 projects, followed by Type 2- and Type 1 projects. Based on the theoretical underpinnings of the work (see section 2.4), the developed conceptual framework (see section 3.2), the underlying research model (see section 3.6.1), and the findings of the case study research (see chapter 4) these differences can be explained by the characteristics of the different project types and the respective organisational arrangements.

As illustrated above, there exist some significant project type-specific differences concerning the characteristics of R&D projects on the one hand and the respective organisational arrangements on the other hand:

While most Type 1 projects have a time-to-market of more than 4 years, the majority of Type 2- and particularly Type 3 projects have a time-to-market of less than 2 years. In addition, Type 1 projects are compared to Type 2- and Type 3 projects characterised by a higher degree of innovation and a higher degree of uncertainty.

These differences concerning the project characteristics indicate that market-driven forms of resource allocation are most suitable for projects of Type 3 and Type 2, whereas the application of market-driven forms of resource allocation can cause problems when it comes to Type 1 projects. Potential problems can occur because of the long time-to-market and the corresponding high degree of uncertainty and high degree of innovation.

These project characteristics possibly impede mutual agreements between suppliers and requestors in an internal R&D market. Since the suppliers cannot give a binding guarantee for a certain project outcome, the requestors cannot be sure if the requested services will be valuable at all. This makes it difficult when it comes to negotiations about prices and conditions. Moreover, the performance of the involved decision-makers is often evaluated on the basis of short-term financial achievements, which in turn can lead to a neglect of long-term Type 1 projects in internal R&D markets.

The mentioned problems also explain the fact why the resources for very long-term Type 1 projects are often allocated via hierarchical mechanisms and are financed by corporate funds. Nevertheless, the survey results also showed that market-driven forms of resource allocation are not only applied for Type 2- and Type 3 projects, but also for Type 1 projects – especially when these projects have a relatively short time-to-market.

The other factor that facilitates the application of market-driven forms of resource allocation is a decentralised R&D organisation. While a centralised R&D organisation normally goes hand in hand with the application of hierarchical forms of resource allocation, a more decentralised R&D organisation, in most cases, is a good indicator for a more market-driven resource allocation.

This means that decentralised organisational arrangements can lead to the fact that a higher proportion of the budgets are determined by the direct interaction of supply and demand. As the presented survey results show, Type 1 projects are rather characterised by centralised organisational arrangements, whereas Type 2- and particularly Type 3 projects are predominantly characterised by decentralised organisational arrangements.

Based on the survey results it can be argued that a decentralised determination of budget, a decentralised project selection, and a decentralised implementation of projects enable the application of market-driven forms of resource allocation.

Furthermore, this organisational separation of research activities on the one hand and development activities on the other hand provides the basis for a multitude of potential supply-and-demand-relationships within the scope of an internal R&D market:

A major relation, for example, is that individual divisions or business units could assign the central research directly with providing certain research services. Likewise, it would be conceivable that the central research assigns certain development orders to that decentralised R&D unit, which can provide the demanded service to the most favourable conditions. In both cases it is about the interface management between central research units on the one hand and the divisions and/or business units on the other hand.

A further important interface is between the R&D units and the units that are close to markets and customers (divisions, business units, marketing companies etc.). Successful R&D is characterised particularly by the fact that R&D recognises the needs of the customers and converts them into innovative customer/market-related products. Thus, the marketing and selling units play an important role in managing this interface successfully.

In summary it can be stated that the application of market-driven forms of resource allocation mainly depends on the project characteristics and the organisational arrangements. A short time-to-market, a high degree of routine and a high degree of certainty as well as decentralised organisational arrangements concerning the determination of budget, the project selection and the implementation of projects enable market-driven forms of resource allocation. Thus, it can be concluded that the application of market-driven forms of resource allocation is particularly possible for Type 3- and Type 2 projects, and in some cases also for Type 1 projects.

### **Allocation result**

In a fourth step, the project type-specific differences concerning the allocation result (effectiveness/efficiency) were analysed. In general, it can be stated that – independent of the project type – market-driven forms of resource allocation were judged as being more effective and efficient than hierarchical forms of resource allocation.

However, the survey results showed only significant project type-specific differences for the effectiveness of direct assignments and the efficiency in terms of an improved adaptability.

Type 3- and Type 2 projects are compared to Type 1 projects characterised by a higher effectiveness of direct assignments and a higher efficiency of market-driven forms of resource allocation in terms of an improved adaptability to changes in the environment. In practice the term ‘direct assignment’ is often used as the synonym for market-driven forms of resource allocation.

Based on the theoretical underpinnings of the work (see section 2.4), the developed conceptual framework (see section 3.2), the underlying research model (see section 3.6.1), and the findings of the case study research (see chapter 4) it can be assumed that the allocation result (effectiveness/efficiency) depends on the characteristics of R&D projects, the organisational arrangements and the applied form of resource allocation.

Concerning the characteristics of R&D projects, it can be stated that market-driven forms of resource allocation are favourable if the projects are characterised by a high potential for short-term commercialisation (low time-to-market), a high degree of routine, and a high degree of certainty. These characteristics enable potential suppliers to precisely estimate the costs associated with the implementation of certain projects and to give binding guarantees for certain project outcomes. Moreover, the potential requestors can precisely estimate the value of certain projects. Thus, the informational asymmetries between potential suppliers and potential requestors are relatively low. This in turn facilitates negotiations about prices and conditions. As the survey results showed, these characteristics are fulfilled the most by Type 3 projects, followed by Type 2- and Type 1 projects.

Additionally, the project type-specific organisational arrangements play an important role in this context. As discussed above, the organisational separation of research activities on the one hand and development activities on the other hand provides the basis for a multitude of potential supply-and-demand-relationships within the scope of an internal R&D market. Based on the presented survey results it can be assumed that a high degree of decentralisation concerning the determination of budget, the project selection and the implementation of projects has positive effects on the allocation result of market-driven forms of resource allocation. According to the findings of the survey these conditions are mostly fulfilled by Type 3 projects, followed by Type 2- and Type 1 projects.

Based on the quantitative analysis it can be further assumed that the applied form of resource allocation has major implications on the allocation result. It can be argued that the favourability of market-driven forms of resource allocation strongly depends on the direct interaction between suppliers and requestors, without interference of centralised decision-committees. As illustrated above, a strong interaction of supply and demand normally goes hand in hand with a high share of projects that is initiated by the requesting units and a high financing share of the requesting divisions/business units. These characteristics are mostly fulfilled by Type 3 projects, followed by Type 2- and Type 1 projects, and they are in accordance with the definition of an internal R&D market (refer to the conceptual framework presented in section 3.2). Thus, it is obvious that a market-like design of the resource allocation processes has positive effects on the allocation result of market-driven forms of resource allocation.

On the basis of the conditions discussed above it can be concluded that market-driven forms of resource allocation are most effective and efficient for Type 3- and Type 2 projects, followed by Type 1 projects.

The research findings presented in this chapter were solely based on descriptive and bivariate analyses. The reasons why a more sophisticated statistical approach (multivariate analysis) was not taken were already discussed in section 3.9. The major implication of this decision was that it was not possible to control for 'ceteris paribus' conditions (see Studenmund, 2001). Specifically, the following statistical methods could have been applied in the context of the present inquiry:

- Binomial (binary) logistic regression
- Multinomial logistic regression

Binomial logistic regression is a form of regression which is used when the dependent is a dichotomy and the independents are of any type. Multinomial logistic regression exists to handle the case of dependents with more classes than two (McKelvey & Zavoina, 1994).<sup>58</sup> In other words, multinomial logistic regression is an extension of binomial logistic regression that allows the simultaneous comparison of more than one contrast. That is, the log odds of three or more contrasts are estimated simultaneously (i.e. the probability of Type 1 vs. Type 2, Type 1 vs. Type 3, and Type 2 vs. Type 3).

Logistic regression can be used (cf. Hosmer & Lemeshow, 1989; Kleinbaum, 1994; Fox, 2000; Jaccard, 2001):

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<sup>58</sup> When multiple classes of the dependent variable can be ranked, then ordinal logistic regression is preferred to multinomial logistic regression.

- to predict a dependent variable on the basis of independents,
- to determine the percent of variance in the dependent variable explained by the independents,
- to rank the relative importance of independents,
- to assess interaction effects, and
- to understand the impact of covariate control variables.

Logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable (the natural log of the odds of the dependent occurring or not; cf. Allison, 1999). In this way, logistic regression estimates the probability of a certain event occurring. In this context it has to be noted that logistic regression calculates changes in the log odds of the dependent, not changes in the dependent itself as ordinary least squares (OLS) regression does.

Logistic regression has many analogies to OLS regression (DeMaris, 1992):

- logit coefficients correspond to b coefficients in the logistic regression equation,
- the standardised logit coefficients correspond to beta weights, and
- a pseudo  $R^2$  statistic is available to summarise the strength of the relationship.

Unlike OLS regression, however, logistic regression does not assume linearity of relationship between the independent variables and the dependent, does not require normally distributed variables, does not assume homoscedasticity, and in general has less stringent requirements. The success of the logistic regression can be assessed by looking at the classification table, showing correct and incorrect classifications of the dichotomous, ordinal, or polytomous dependent. Also, goodness-of-fit tests such as model chi-square are available as indicators of model appropriateness as is the Wald statistic to test the significance of individual independent variables (DeMaris, 1992; Allison, 1999; Bühl & Zöfel, 2002).

In the context of the present investigation the nominal scaled project types could have served as dependent variables. As mentioned above the relevant questions of my questionnaire had a 5 point Likert scale. This implied that the independent variables had ordinal scales. Given these levels of measurement the application of multinomial logistic regressions would have been the most appropriate method for testing the project type-specific differences (research question 1; cf. Hosmer & Lemeshow, 1989; Kleinbaum, 1994; Fox, 2000; Jaccard, 2001).

*“If there are  $n$  alternatives, there should be  $n-1$  different logit equations in the multinomial logit model system, because the coefficients of the last equation can be calculated from the coefficients of the first  $n-1$  equations.”* (Studenmund, 2001 p.451). Since the inquiry focused on three project types, a potential multinomial logit model would have a system of two equations:

$$\ln\left(\frac{P_{si}}{P_{bi}}\right) = \alpha_0 + \alpha_1 X_{1i} + \alpha_2 X_{2i}$$

$$\ln\left(\frac{P_{ci}}{P_{bi}}\right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i}$$

- where: s = Projects of Type 2
- c = Projects of Type 3
- b = Projects of Type 1 (“base” alternative)
- X = Characteristics of the project types (e.g. time-to-market)

Concerning the applicability of market-driven forms of resource allocation (research question 2) and the superiority of market-driven forms of resource allocation (research question 3) a somewhat different approach would have been suitable. In these cases the dependent variables were dichotomous (e.g. 1=market possible; 0=market not possible) and the independent variables again were ordinal. Thus, binomial (or binary) logistic regression analysis would have been the most appropriate method in this context (Hosmer & Lemeshow, 1989; Kleinbaum, 1994; Fox, 2000; Jaccard, 2001).

For example, a potential hypothesised equation could have been:

$$D_i = f(A_i, B_i, C_i, D_i, E_i, F_i, G_i, \dots) + \epsilon_i$$

$$D_i = \begin{cases} 1 & \text{if the } i\text{th project type is coordinated via internal R\&D markets} \\ 0 & \text{if the } i\text{th project type is coordinated via hierarchy} \end{cases}$$

- where: A<sub>i</sub> = degree of routine of the *i*th project type
- B<sub>i</sub> = degree of certainty of the *i*th project type
- C<sub>i</sub> = degree of short-term commercialisation of the *i*th project type
- D<sub>i</sub> = degree of decentralisation of the *i*th project type
- E<sub>i</sub> = degree of direct interaction of supply and demand of the *i*th project type
- F<sub>i</sub> = a dummy variable equal to 1 if the R&D quota of the company is higher than 3.5%, 0 otherwise
- G<sub>i</sub> = a dummy variable equal to 1 if the number of R&D co-workers of the company is higher than 1000, 0 otherwise

As illustrated in the equation above, the application of multivariate analysis also would have made it possible to test for control variables/dummy variables,<sup>59</sup> such as R&D quota, number of R&D co-workers, industry or number of projects, which could have revealed additional valuable insights.

Nevertheless, it has to be noted at this juncture that the survey is only one part of the empirical studies and is complemented by two other parts (case study research and group interviews). Based on this triangulation approach it can be stated that the research findings of this study provide consistent, cumulative evidence compatible with the arguments of this thesis. The conducted descriptive and bivariate analysis of the quantitative data helped to sharpen the understanding of the research topic and to explore fundamental relationships. In addition, the findings of the survey provided crucial information for the derivation of policy recommendations (see section 7.2). However, before these recommendations could be developed the research findings were validated and verified within the scope of a set of group interviews with practitioners. The research findings associated with these group interviews are outlined in the following chapter.

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<sup>59</sup> “A dummy variable takes on the values of one or zero depending on whether a specified condition holds.” (Studenmund, 2001 p.66).

## **6 Findings of the group interviews**

### **6.1 Introduction**

In order to validate and verify the research findings a set of group interviews were conducted at this stage of the research process. These group interviews helped to clarify the content of some of the questionnaire results and to get at the meaning behind some of the data. The methodological issues associated with the group interviews were discussed in section 3.7.

In general, this third part of the process of triangulation mainly aimed at fulfilling the following two purposes:

- Seeking confirmation of previous findings by R&D experts
- Create added-value for the derivation of policy recommendations by capitalising upon the opinions and knowledge of practitioners

This chapter is organised in accordance with the structure of the presented research findings of the case studies (chapter 4) and the survey (chapter 5). Thus, it comprises the following aspects:

- Characteristics of R&D project types (section 6.2),
- R&D organisation (section 6.3),
- R&D resource allocation (section 6.4), and
- Allocation result (section 6.5).

Finally, section 6.6 summarises the major findings of the group interviews.

### **6.2 Characteristics of R&D project types**

In a first step, the different characteristics of the investigated R&D project types were discussed. The previous research findings showed that these project types can be mainly differentiated on the basis of the following characteristics:

- degree of routine,
- degree of certainty, and
- time-to-market.

Within the scope of the group interviews the R&D experts confirmed that these characteristics are most appropriate for distinguishing the project types.

However, there was mutual agreement that the characteristic time-to-market is by far the most important aspect for the categorisation of R&D projects. The experts pointed out that it is often beneficial to increase the expenditures for certain

R&D projects in order to reduce the time-to-market and thereby allowing the companies to capitalise upon so-called first-mover advantages. Competition in the global market place makes it more and more important to be first with new products, so one expert.

As mentioned above, the group interviews mainly aimed at deriving policy recommendations for the design of internal R&D markets. In this context the practitioners argued that it is important to take into consideration that different companies of different industries may have different project typologies. Therefore, they proposed the creation of a universally applicable model. With the help of this model it shall be decided whether a certain R&D project can be traded via an internal R&D market or not.

The R&D experts were of the opinion that this model on the one hand should be based on the project characteristics mentioned above. This means that each R&D project has to be evaluated concerning its degree of routine, degree of certainty and time-to-market. These characteristics could serve as a first indicator for the decision if the application of market-driven forms of resource allocation is possible, in principle. The R&D experts found this procedure sophisticated since it enables companies from different industries to cluster their projects in a new way, without taking into account the respective project type.

On the basis of the presented findings of the case study research and the survey research it was concluded that market-driven forms of resource allocation are particularly suitable for R&D projects that are characterised by a high degree of routine, a high degree of certainty and a high potential for short-term commercialisation (short time-to-market). The practitioners confirmed that these characteristics are mostly fulfilled by enhancement projects (Type 3) and new development projects (Type 2), followed by Research & Technology projects (Type 1).

Given these project type-specific differences, the discussion focused on the possibility of applying market-driven forms of resource allocation for Research & Technology projects. One expert mentioned that his company undertakes ongoing efforts to directly assign R&T projects to internal and/or external R&D labs. However, he stated that this is currently only possible for R&T projects that are associated with applied research, i.e. where the project characteristics mentioned above are mostly fulfilled. For basic research projects, however, market-driven forms of resource allocation are currently not an option, so the R&D manager. In this context another expert argued that things may be different when a basic research project has been finished. Then a certain result is available that can be offered via an internal R&D market. In this way requesting divisions and/or business units can place new orders that are based on the available results, or they can purchase these results in order to develop marketable products or processes.

Concerning the question under which circumstances market-driven forms of resource allocation are possible, the group discussions revealed that the organisational arrangements also play an important role, in addition to the project characteristics.

### 6.3 R&D organisation

Within the scope of the conducted studies the following organisational arrangements were identified as the main enablers for the application of market-driven forms of resource allocation:

- decentralised determination of budget,
- decentralised project selection, and
- decentralised implementation of projects.

These findings were unanimously confirmed by the R&D experts. They also confirmed that on the one hand development activities are predominantly organised decentrally, i.e. enhancement projects (Type 3) and new development projects (Type 2). The research activities on the other hand are predominantly organised centrally, i.e. Research & Technology projects (Type 1).

In this context the consulted experts mentioned that there is an ongoing trend towards a stronger decentralisation of research activities. This trend is in accordance with the principle 'think global, act local'.

It was concluded that decentralised organisational structures have positive impacts on the applicability of internal R&D markets. Thus, a decision model for the applicability of internal R&D markets has to consider the project characteristics on the one hand and the organisational arrangements (enablers) on the other hand.

At this juncture the practitioners added a further important aspect to the discussion. They pointed out that powerful IT infrastructure is needed for the establishment of internal R&D markets. This is also underpinned by the general organisational conditions that prevail in huge technology-intensive companies. One expert, for example, mentioned that his company has several hundreds of internationally dispersed locations. Each year about 8000 R&D co-workers implement more than 1000 R&D projects simultaneously. Moreover, in some larger projects up to 25 R&D units are involved, which are located in different countries. On this basis he emphasised that the required coordination and communication efforts are immense. Thus, he was of the opinion that the establishment of an internal R&D market could be beneficial in terms of an increased transparency, but only if the underlying IT infrastructure is reliable and powerful enough.

In this context another expert reported about the ongoing efforts of his company to establish an intranet-based R&D portal. This was designed to become the forum for members of the R&D community and colleagues working closely together with R&D. It also functions as a window on the activities of the R&D community for the whole company. It should be used as a virtual forum in order to foster the interchange of expertise and to stimulate networking, thus, complementing but never replacing face-to-face communication. In the center of the portal, a content area informs users about relevant news and developments inside and outside the R&D community. Beside this, some additional features are available: events calendar; links to R&D units; activities; services and publications. All

sensitive information is password protected. For the future the portal should become a working tool for all members of the R&D community offering a direct work-flow support.

From an organisational point of view such an intranet-based R&D portal would provide the ideal platform for the R&D resource allocation via internal R&D markets, so the mutual agreement of the involved experts.

## 6.4 R&D resource allocation

Concerning the R&D resource allocation, the research findings showed that market-driven forms of resource allocation are particularly characterised by:

- the direct interaction of supply and demand,
- a high share of projects which is initiated by the demand side, and
- a high financing share of the requesting divisions and/or business units.

In general, this was confirmed by the interviewed R&D experts. They stated that market-driven forms of resource allocation are currently most often applied for enhancement projects (Type 3) and new development projects (Type 2), followed by Research & Technology projects (Type 1). The experts explained these project type-specific differences with the different project characteristics and organisational arrangements. Particularly a short time-to-market in combination with a decentralised R&D organisation were identified as the main enablers.

However, the experts emphasised that market-driven forms of resource allocation are not an established standard in R&D practice. Moreover, the discussion made clear that in reality there are numerous different forms of resource allocation processes. In this context the interviewees of the group interviews pointed out that it is therefore important to firstly determine the actual state concerning the prevailing resource allocation before potential designs of an internal R&D market are developed. Only on the basis of existing structures and processes it makes sense to undertake any reorganisation efforts towards 'more market,' so the unanimous opinion of the experts.

The group discussions illustrated that it is on no account about the establishment of internal R&D markets in their 'pure' form, but rather about the improvement of already existing market-like elements or the establishment of additional market elements in order to increase the efficiency of the internal R&D resource allocation.

As potential design elements the elements of the conceptual framework were introduced (refer to section 3.2). These elements were validated by the practitioners. But again, they remarked that in practice there are a multitude of design possibilities for each element and that there is no single superior allocation design. Thus, alternative allocation designs must be evaluated against the setting of the company-specific circumstances, so the experts.

Within the course of the discussions it turned out that an intranet-based allocation design is of particular interest for the practitioners. As mentioned above, they were convinced that the Intranet could serve as the basic platform for the establishment of internal R&D markets. In this context a participating R&D manager introduced an intranet-based architecture, which serves as a work-flow tool that supports the R&D management of his company.

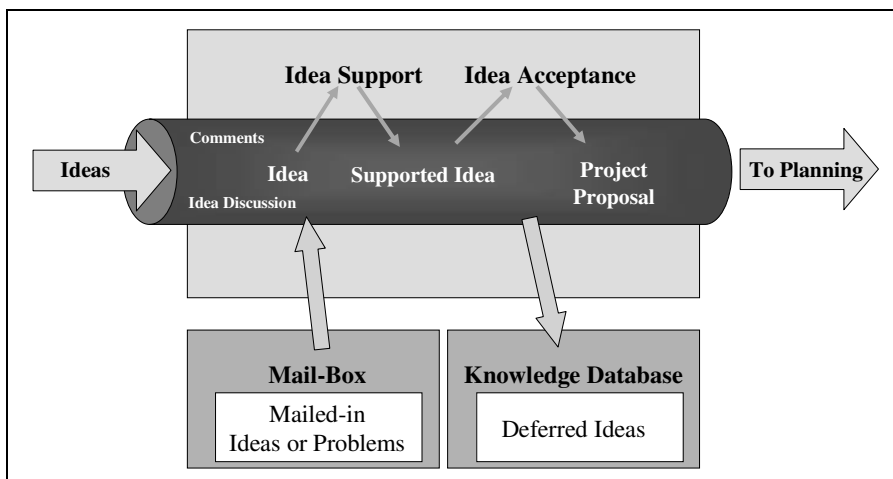
This intranet-based tool consists of the following three parts:

- Idea creation,
- Planning, and
- Project execution.

In a first step, only the core of the idea is presented. This includes the idea itself, the potential business impact of it, and the idea creator's comments. The idea creator decides who will be allowed to read and comment on the idea in order to help him to refine it. There are several possibilities ranging from making it open for only selected persons to making it public within the system. This enables those assigned to enter their comments and suggestions for improvement. Using this possibility the idea is refined, merged with other ideas, or shown to have already been tested. A truly 'virtual team' helps the creator with this.

The next step in the work-flow is to get support for the idea. The aim of this step is to move the idea from the idea stage to a project proposal. Once the idea is supported more details are needed such as defined goals, risks, obstacles, and resources needed. If the idea is supported and necessary information has been entered, the programme manager can choose to make it a real project proposal (idea acceptance).

This transfers all the information to the next part of the intranet-based work-flow tool – the planning application. Ideas that do not succeed in reaching the project proposal stage are saved in the idea database as reference information. The complete idea creation process is illustrated in Figure 47.



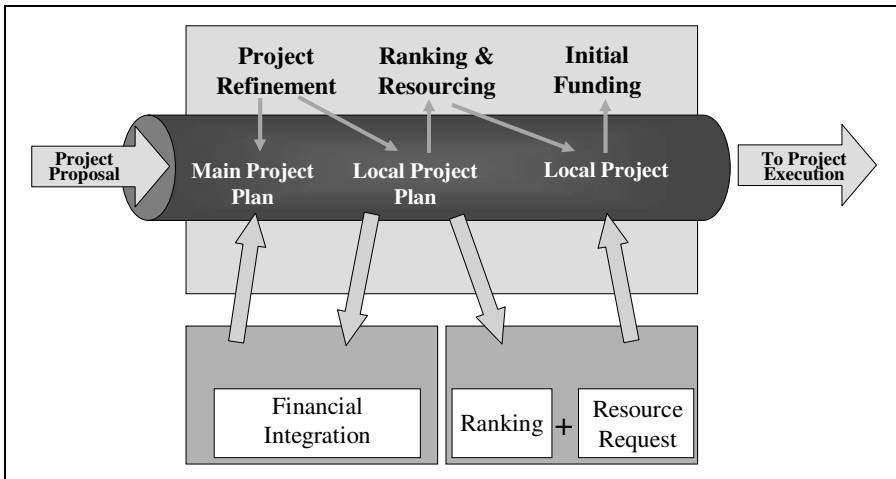
**Figure 47: Intranet-based idea creation**

The subsequent planning application is focusing on matching project proposals with customer needs, R&D resources, and programme strategies. The competent scientists and technicians have the potential to create many more good project proposals than can be executed. Project proposals are entered into the planning application from the idea creation phase. They are now called ‘Main Project Plans’.

At this stage a project leader for the proposed project is assigned. He is responsible for pushing the proposal through the planning phase. First the application works similarly to a ‘quotation system,’ i.e. resources are converted into costs. When it is decided where (in which center or centers) the project should be executed, it is split into one or several local projects. If it is a large project, local project leaders responsible for the part of the project conducted in one center start refining the local project plans in terms of local goals, costs and financing.

The project leader submits the local project or projects for the continuous ranking. The proposed project is reviewed by the programme manager, the local R&D director and business area representatives. Together they give the project a ranking – put the project in one of three priority groups. Rankers will be notified by e-mail. The ranking procedure and status can be monitored by the project leader.

If the project, with all local project plans, was successful in ranking, then the project leader uses the work-flow tool for requesting the local R&D director for resources. If and when they are available, the project is ready for transfer to the execution phase. In order to start executing a project the project leader sends the initial funding request for corporate funding. The project is then transferred to the project execution phase. The complete planning process is outlined in Figure 48.

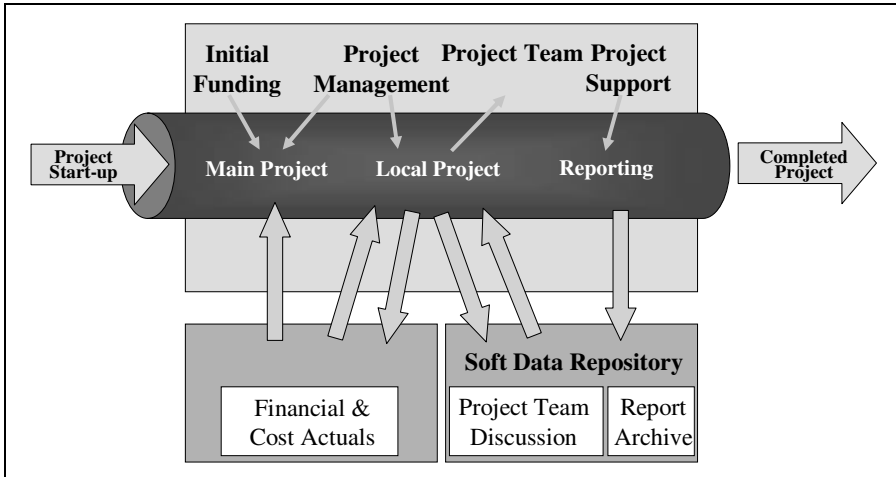


**Figure 48: Intranet-based planning**

Project execution represents the third part of the intranet-based work-flow tool. This phase was created for supporting the project leader in his day-to-day project management. Moreover, a tool for creating and supporting project teams is included. It makes it possible to share information between all team members wherever they are in the world. This is accomplished through a discussion database specific for each project. Each team member can keep the project leader and all other team members up-to-date with what is going on. Thus, everyone can contribute his skills to the success of the project.

The project support provides a simple and formalised way of communicating the most important items of the project both to team members and to management. Project status is summarised in three key elements – status of cost, time and results. Focus for periodic reporting is on highlights, achievements, problems and actions. A report archive function saves the history of the project.

Financial details are entered into the system from the local accounting systems at each R&D center. All this information consolidated into the main project makes it possible to monitor the financial status of cross-border projects. Functions for additional funding requests, forecasts and other administrative issues are also available. All projects running in the project execution application are at the same time present in the planning application for ranking and next year's budgeting purposes. The features associated with the project execution phase are summarised in Figure 49.



**Figure 49: Intranet-based project execution**

The example of the intranet-based work-flow tool illustrates the complexity of designing alternative forms of resource allocation. At the same time this example emphasises the importance of the Intranet as a major design element within the scope of internal R&D markets.

After the introduction of the intranet-based work-flow tool it was discussed whether the establishment of an intranet-based auction design could be beneficial. All of the experts stated that they currently do not use auctions within their resource allocation processes.

However, some practitioners mentioned that there are ongoing efforts towards a more market-oriented allocation of resources and that their companies intend to develop a suitable auction design. Since the idea of an intranet-based auction design is still in its infancy there was mutual agreement that further research in this area is needed.

In conclusion, the group discussions made clear that there are numerous design possibilities for the internal R&D resource allocation. The following section deals with the evaluation of alternative allocation designs.

**6.5 Allocation result**

With regard to the allocation result, the research findings showed that market-driven forms of resource allocation hold an enormous potential concerning the improvement of

- effectiveness, and
- efficiency.

In general, this was confirmed by the interviewed R&D experts. In accordance with the presented research findings they were of the opinion that these positive effects can particularly be realised for enhancement projects (Type 3) and new development projects (Type 2), followed by Research & Technology projects (Type 1).

Concerning the research activities, they pointed out that there might be a risk that internal R&D markets could lead to a neglect of long-term strategic projects, since the market participants are often measured by short-term financial goals. Thus, internal R&D markets need clear regulations and supervision, so the experts. Consequently, it was concluded that there is a need for further research concerning an adequate incentive system within such markets.

Moreover, there were some concerns concerning the costs of establishing internal R&D markets. The practitioners agreed that a company has to consider carefully if the benefits and advantages of a more market-driven resource allocation outweigh the incurred costs and potential risks. In this context the conducted group discussions showed that beside the criteria effectiveness and efficiency also secondary effects must be taken into consideration when deciding upon alternative forms of resource allocation.

The experts argued that the switch from hierarchical forms of resource allocation to market-driven forms of resource allocation can possibly lead to an increased transparency and/or a stronger interaction between the involved parties. This again can lead to the generation of additional ideas and project proposals and to the fact that synergies are identified earlier and thus are used more consequently (so-called positive secondary effects).

However, the increased transparency can also increase the danger that valuable knowledge flows out to unauthorised third parties, e.g. competitors (so-called negative secondary effects). In the view of some R&D experts these negative secondary effects often prevent a more-market-driven resource allocation in R&D practice.

Nevertheless, there was mutual agreement that offering intellectual property, ideas, R&D projects and services, or R&D project results via an intranet-based market place could lead to an improved effectiveness and efficiency in R&D. In addition, an electronic catalogue which contains the offered projects and services could be established as a marketing instrument that increases transparency and facilitates market interactions.

However, the experts had some concerns concerning the security of sensible data. Thus, they argued that different security levels would be needed ranging from strictly personal to public. Without such security measures companies would face the risk that sensible information and knowledge flow out to unauthorised third parties.

These controversial arguments made clear that there was a need to agree on a suitable evaluation model, which considers the following criteria:

- effectiveness (doing the right things)
- efficiency (doing things right), and
- secondary effects (positive or negative side effects).

This model should help to put the subjective opinions of the experts on a more objective basis. In this context the interviewees agreed that it is extremely difficult to exactly quantify the monetary implications associated with a shift from hierarchical to market-driven forms of resource allocation. Thus, an adequate evaluation model needed to consider both qualitative and quantitative measures.

The experts stated that particularly scoring approaches (qualitative) and the net present value method (quantitative) were most often applied in practice. On this basis an evaluation model was developed, which is shown in the policy recommendations (see section 7.2). The developed model for the evaluation of alternative forms of resource allocation was validated and verified by the practitioners. They agreed that this model provides a solid base for the actual design of internal R&D markets.

## 6.6 Summary

In summary, the group interviews made significant contributions to this inquiry. On the one hand the dynamic group discussions created added-value for the derivation of policy recommendations by capitalising upon the opinions and knowledge of practitioners.

Particularly the illustrated practical design of an intranet-based architecture, which could serve as the basis for the establishment of internal R&D markets, added valuable insights to the inquiry.

On the other hand the interviewed experts confirmed the main research findings, concerning the characteristics of R&D project types, the R&D organisation, the R&D resource allocation, and the allocation result. Specifically, the group interviews made the following essential contributions:

### Characteristics of R&D project types

First of all they helped to select the most appropriate characteristics for the categorisation of different types of R&D projects. It was emphasised that the R&D project types can be differentiated on the basis of the following characteristics:

- degree of routine,
- degree of certainty, and
- time-to-market.

In this context the time-to-market was identified as the most important project characteristic. Moreover, the experts agreed that market-driven forms of resource allocation are particularly suitable for R&D projects that are characterised by a high degree of routine, a high degree of certainty and a high potential for short-term commercialisation (short time-to-market). The practitioners confirmed that these characteristics are mostly fulfilled by enhancement projects (Type 3) and new development projects (Type 2), followed by Research & Technology projects (Type 1).

### **R&D organisation**

Moreover, the experts confirmed that certain project characteristics in combination with certain organisational arrangements enable market-driven forms of resource allocation. In this context the following organisational arrangements were identified as the main enablers for the application of market-driven allocation forms:

- decentralised determination of budget,
- decentralised project selection, and
- decentralised implementation of projects.

The practitioners confirmed that enhancement projects (Type 3) and new development projects (Type 2) are mainly organised decentrally, whereas Research & Technology projects (Type 1) are predominantly organised centrally.

In order to decide whether the application of internal R&D markets is possible or not, the R&D experts proposed the creation of a universally applicable model.

Therefore, based on the project characteristics on the one hand and the organisational arrangements on the other hand, a model was developed that illustrates under which circumstances certain R&D projects can be traded via an internal R&D market. This model is one essential part of the policy recommendations, which are shown in section 7.2.

### **R&D resource allocation**

Concerning the R&D resource allocation, the R&D experts confirmed that market-driven forms of resource allocation are particularly characterised by:

- the direct interaction of supply and demand,
- a high share of projects which is initiated by the demand side, and
- a high financing share of the requesting divisions and/or business units.

They also confirmed that market-driven forms of resource allocation are most often applied for enhancement projects (Type 3) and new development projects (Type 2), followed by Research & Technology projects (Type 1).

In this context the interviewed experts pointed out that potential reorganisation efforts towards a more market-driven allocation of R&D resources must be based on the actual state concerning the prevailing structures and processes. On this basis, so their suggestion, one or several alternative allocation designs can be developed.

Moreover, the practitioners validated the elements of internal R&D markets, as they were outlined in the conceptual framework in section 3.2. These features give the potential 'designer' (e.g. management board) of an internal R&D market a clue which elements can be designed, in principle. However, the experts remarked that the decision-makers have to bear in mind that for each element numerous designs are basically conceivable and that there is no single superior allocation design.

In this way the group interviews helped to determine a set of elements for the design of internal R&D markets. These design elements constitute a further essential part of the policy recommendations, which are shown in section 7.2.

### **Allocation result**

Concerning the allocation result, the practitioners confirmed that market-driven forms of resource allocation are most effective and efficient for enhancement projects (Type 3) and new development projects (Type 2), followed by Research & Technology projects (Type 1).

Moreover, the group discussions were also helpful for the development of a model for the evaluation of the favourability of internal R&D markets. The practitioners agreed that the evaluation of alternative forms of resource allocation should be based on the following three criteria:

- effectiveness (doing the right things)
- efficiency (doing things right), and
- secondary effects (positive or negative side effects).

Furthermore, the experts preferred a mix of qualitative and quantitative methods (i.e. scoring approach in combination with the net present value approach) for the evaluation of the favourability of alternative forms of resource allocation. This provided the basis for the development of a mutually accepted evaluation model. This model is explained within the scope of the policy recommendations, which are outlined in section 7.2.

In the following chapter conclusions are drawn with regard to the conducted research. The main research results of this inquiry are summarised in section 7.1. The subsequent section 7.2 presents a set of policy recommendations, which were derived on the basis of the conducted studies. Finally, section 7.3 provides a critical appraisal of the work done.

## 7 Conclusions

### 7.1 Main results

The present investigation was based on the following general research problem: How could and should scarce resources (human resources, funds etc.) be allocated between competing R&D projects? In this context it was emphasised that structures and processes in R&D have to be in line with the strategy of the enterprise and market needs, in order to avoid costs, to reduce time-to-market and thus to obtain higher profits. On this basis it was argued that it is of increasing importance to allocate existing scarce resources to those R&D projects, which add the highest value to the company.

It was pointed out that two main forms of R&D resource allocation can be differentiated, in principle: The administrative, hierarchical allocation on the one hand and the allocation via internal markets on the other hand. In between there are a multitude of hybrid forms of resource allocation that are characterised by a mix of hierarchical and market-like elements.

Supporters of the internal market concept are of the opinion that hierarchical structures increasingly come up against limiting factors, because of the increasing complexity and dynamic of the relevant environment. Thus, they argue that the use of flexible internal market mechanisms is the organisational concept for the future. However, in this connection there are also some critics that warn of the uncritical transfer of external market structures and mechanisms to the internal context of a company because of strongly varying basic conditions.

The preliminary investigations showed that in spite of the weaknesses of hierarchical decision processes a rather hierarchical, administrative organisation still prevailed in R&D. Moreover, these studies made clear that market-driven forms of resource allocation are not an established standard within the scope of internal R&D resource allocation processes. Thus, the central research intention of this work was to investigate if and under which conditions the application of market-driven forms of resource allocation is possible and superior compared to existing hierarchical, administrative forms of resource allocation.

Therefore, in a first step, the literature of relevance was synthesised and evaluated. First, the traditional hierarchical resource allocation was discussed. It was illustrated that research activities on the one hand and development activities on the other hand are usually separated from an organisational point of view. As the main characteristic feature of the hierarchical allocation the central decision-maker, respectively, the central decision-committee was mentioned. These decision-makers determine the nature and the quantities of the goods and/or services and are thus responsible for the allocation of the corresponding budgets. The projects themselves are conducted by the respective project managers and their teams.

Furthermore, the typical stages of the hierarchical decision process, from the generation of ideas via the project selection up to the market launch, were illustrated. As the main decision instruments for the allocation decisions, the most frequently used quantitative and qualitative evaluation methods were introduced. The explained methods (net-present-value method, decision tree analysis, scoring approaches) serve as essential decision instruments and help making estimates about potential economic implications of the respective allocation and/or reallocation decisions.

In this context the following main problems of the hierarchical resource allocation were identified:

- long communication and decision procedures,
- decision-makers have lack of information,
- informational asymmetries between decision-makers (principals) and subordinates (agents) and the resulting opportunistic behaviour of subordinates.

On this basis it was argued that these rigid and inflexible hierarchical organisation structures can lead to inefficiencies and misallocations within the scope of R&D resource allocation. Therefore, it was pointed out that market-driven forms of resource allocation can possibly help to overcome the mentioned problems of hierarchical resource allocation forms. This assumption was also underpinned by the fact that there has been a broad trend towards a stronger market-orientation of the R&D activities in recent years.

On the basis of several selected statements it was demonstrated that in the existing literature there is no uniform understanding of the term 'internal market'. Initial articles describe internal markets as a form of hierarchical resource allocation between divisions of diversified companies. Somewhat later, in the early nineties, many companies established internal markets for the first time in form of profit centers combined with the use of modern information and communication technology. This development provided the basis for a more intensive discussion in the scientific literature, which was presented in the literature review.

The literature review illustrated that the cited literature regarding internal markets is predominantly concerned with the hierarchical, administrative organisation of the internal resource allocation and reallocation processes in a firm. But nothing is said about establishing 'real' internal markets within an enterprise, respectively, within the R&D resource allocation. Given this research 'lacunae,' the thesis in hand explicitly focused on the allocation of scarce resources on single R&D projects via internal markets.

In this context the following research questions were formulated:

RQ1: Are there differences across R&D project types concerning (1) the project characteristics, (2) the R&D organisation, (3) the R&D resource allocation, and (4) the allocation result?

RQ2: For which types of R&D projects are market-driven forms of resource allocation possible?

RQ3: For which types of R&D projects are market-driven forms of resource allocation more effective and/or efficient than hierarchical forms of resource allocation?

RQ4: How should an internal market within R&D be designed?

To answer these research questions it was important to take a closer look at the topic 'internal R&D markets,' both from a theoretical as well as from an empirical point of view.

In this context the underlying methodological approach was explained and justified. First of all there was a need to develop a conceptual framework. This framework should ensure a uniform understanding of the term 'internal R&D market'. It was argued that the implementation of internal markets is nothing else than the attempt to reconstruct elements and principles of free-market systems within a company. Therefore, on the basis of the reference model 'external markets,' the main market elements were identified, in order to discuss them subsequently in the context of the internal R&D resource allocation. Based on this analysis the following definition of an internal R&D market was developed:

An internal R&D market is:

- an (electronically) platform (market place)
- that is regulated by the management (supervision)
- and on which internal R&D suppliers and R&D requestors (actors) with equal rights (hierarchically independent)
- that are in charge of different resources
- carry out transactions (exchange processes)
- within the scope of a (communicative) competition
- according to their individual preferences (value-maximisation)
- by taking into consideration the (negotiated or auctioned) prices for intellectual property, ideas, R&D services and/or R&D projects or R&D results (transaction objects)
- and have the right to fully appropriate the resulting profits from these transactions due to informal or formal contracts (profit responsibility).

This definition served as the basis for the implementation of the empirical studies.

Subsequently, it was pointed out that a mixed-method approach appeared to be appropriate for the research inquiry, i.e. a sequential triangulation of research techniques was used, including case study research, survey research, and group interviews.

The conducted case studies were particularly useful for the identification of topic-relevant factors, variables and relationships. Furthermore, the analysis of existing R&D resource allocation processes helped to identify potential starting points for the application of internal R&D markets. A further essential purpose of the case studies was the analysis of the actual situation in the companies as well as the preparation of the international survey. Based on the insights of the literature review and the case studies the research model was conceptualised and the basic hypotheses were refined.

In a further step, the methodological approach concerning the international survey was explained. Beside the research model, also the research arrangements and instruments as well as the investigation objects were discussed. Since the topic 'internal R&D markets' is only of interest for huge international groups the population was limited to a relatively small number of 281 companies. In total 45 responses were received, which meant a response-rate of 16.01%. The gathered quantitative data from the survey were used to test the derived hypotheses and to illustrate the relationships between the relevant variables.

In order to validate and verify the empirical findings and to derive policy recommendations for the design of an internal R&D market, a set of group interviews were finally conducted. These interviews with experts from the partner companies helped to clarify the content of some of the empirical results and to get at the meaning behind some of the data. Moreover, they provided additional valuable data concerning the practical design of internal R&D markets.

After the discussion of the methodological approach the empirical findings of the case studies were presented and analysed. The findings of the case study research were particularly important for the preparation and design of a questionnaire for the subsequent survey stage.

As the case studies showed, the following three types of R&D projects can be distinguished in practice:

- Type 1: Research & Technology projects<sup>60</sup>
  - Type 1a: R&T projects aimed at new businesses and markets
  - Type 1b: R&T projects aimed at existing businesses and markets
- Type 2: Projects for the development of new products and processes<sup>61</sup>
- Type 3: Projects for the enhancement of existing products and processes<sup>62</sup>

Furthermore, it was shown that the **different project types are conducted in different organisational arrangements**. While the research activities (projects of Type 1) are predominantly conducted centrally, the development activities (projects of Type 2 and Type 3) are predominantly conducted in the decentralised divisions and/or business units, respectively, in the corresponding development units. According to that the following two main interfaces for market-like exchange relationships were identified: On the one hand between the requesting divisions/business units and the central research units. On the other hand between the units, which are close to markets and customers (e.g. marketing companies), and the R&D units.

Concerning the resource allocation, it was shown that **depending on the project type different forms of resource allocation are applied**. The resources for R&T projects aimed at new businesses and markets (Type 1a) are predominantly allocated hierarchically via centralised decision-committees. Market-like elements, such as direct assignments or transfer prices, are mainly applied for the enhancement projects of Type 3. However, the part of R&T projects aimed at existing businesses and markets (Type 1b) as well as the new development projects of Type 2 are rather characterised by an allocation mix of hierarchical and market-like elements. So, for these kinds of projects often the market element of direct assignments is applied, but the actual project selection mainly takes place via centralised decision-committees.

Concerning the evaluation of the alternative forms of resource allocation, the case studies showed that there seems to be an **association between the project type and the effectiveness and/or efficiency of internal R&D markets**. While internal R&D markets were judged as being more effective for Type 2 projects and particularly for Type 3 projects, hierarchical forms of resource allocation were preferred for Type 1 projects. Concerning the efficiency of internal R&D markets, in comparison to hierarchical forms of resource allocation, the case studies

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<sup>60</sup> Objective is to gain insights (e.g. basic research, applied research, methodology research).

<sup>61</sup> Objective is the development of new marketable products/processes.

<sup>62</sup> Objective is the development of product enhancements (derivatives) and process enhancements, based on existing products and processes.

showed rather indifferent results. However, a slight tendency for efficiency improvements through the application of internal R&D markets for Type 2- and Type 3 projects was identifiable.

In general, the findings of the **subsequently conducted survey confirmed the results of the case study research**. Moreover, the raised quantitative data helped to identify major relationships between the investigated variables. In this way the survey results provided the basis for answering the set up research questions and for making generalising statements concerning the topic ‘internal R&D markets’.

The results showed that a useful differentiation of the investigated project types can be made on the basis of the characteristics degree of routine, degree of certainty and time-to-market. **The analysis indicated that Type 3 projects are compared to Type 2- and particularly Type 1 projects characterised by a higher degree of routine, a higher degree of certainty and a higher potential for short-term commercialisation**. Vice versa Type 1 projects are compared to Type 2- and particularly Type 3 projects characterised by a higher degree of innovation, a higher degree of uncertainty and a higher time-to-market.

Concerning the R&D organisation, the findings of the survey illustrated that R&D activities are organisationally separated from each other. This is reflected in the project type-specific degree of decentralisation concerning the determination of budget, the project selection, and the implementation of projects. **The results showed that Type 2 projects and particularly Type 3 projects are characterised by a relatively high degree of decentralisation, whereas Type 1 projects are characterised by a relatively high degree of centralisation**.

**Certainly market-driven forms of resource allocation are not an established standard in the R&D field, but it was shown that depending on the respective project type different forms of resource allocation are applied**. Significant project type-specific differences were found for the following aspects: Type 3- and Type 2 projects are compared to Type 1 projects characterised by a higher share of budget which is determined by the interaction of supply and demand, a higher share of projects that is initiated by the demand side, and a higher financing share of the requesting divisions/business units. These results illustrated that **market-driven forms of resource allocation are most often applied for Type 3- and Type 2 projects, followed by Type 1 projects**.

In a further step, the project type-specific differences concerning the allocation result were analysed. The survey results showed the following significant project type-specific differences concerning the effectiveness and efficiency of market-driven forms of resource allocation: On the one hand concerning the effectiveness of direct assignments and on the other hand concerning the efficiency in terms of an improved adaptability. **The findings showed that Type 3- and Type 2 projects are compared to Type 1 projects characterised by a higher effectiveness of direct assignments and a higher efficiency in terms of an improved adaptability to changes in the environment**. Beside these differences it can be stated that – independent of the project type – market-driven forms of resource

allocation were on average judged as being more effective and efficient than hierarchical forms of resource allocation.

Table 34 shows the revealed project type-specific differences in an overview and thereby answers the first research question, which was:

*RQ1: Are there differences across R&D project types concerning (1) the project characteristics, (2) the R&D organisation, (3) the R&D resource allocation, and (4) the allocation result?*

	Type 1	Type 2	Type 3
<b>A) Project Characteristics</b>			
- degree of routine	low	<----->	high
- degree of certainty	low	<----->	high
- potential for short-term commercialisation	low	<----->	high
<b>B) R&amp;D Organisation</b>			
- decentralised determination of budget	low	<----->	high
- decentralised project selection	low	<----->	high
- decentralised implementation of projects	low	<----->	high
<b>C) R&amp;D Resource Allocation</b>			
- interaction of supply and demand	low	<----->	high
- share of projects that is initiated by the demand side	low	<----->	high
- financing share of requestors	low	<----->	high
<b>D) Allocation Result</b>			
- effectiveness of direct assignments	low	<----->	high
- efficiency in terms of an improved adaptability	low	<----->	high

**Table 34: Project type-specific differences**

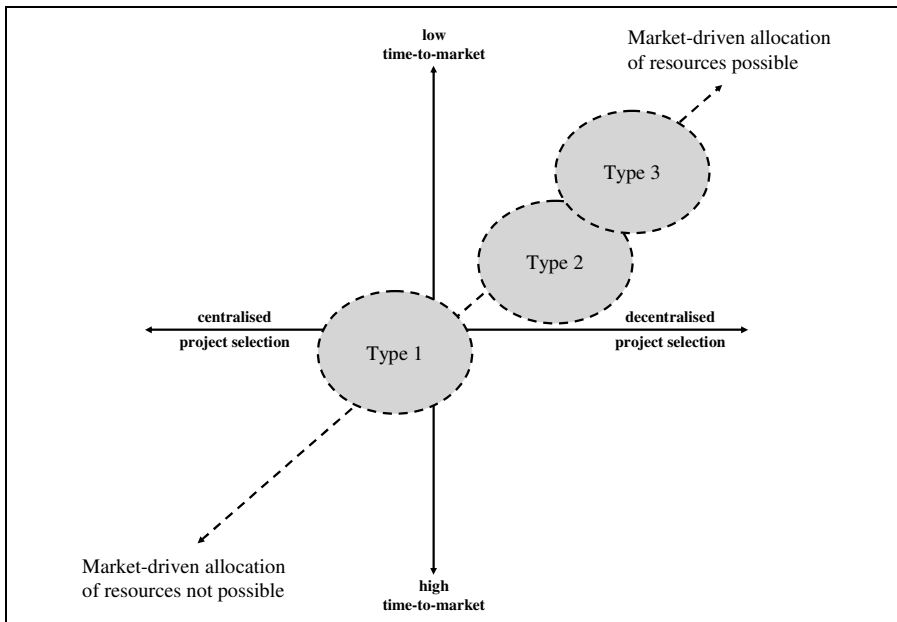
On the basis of these project type-specific differences the second and the third research question were answered. The second research question was:

*RQ2: For which types of R&D projects are market-driven forms of resource allocation possible?*

The research findings showed that the application of market-driven forms of resource allocation is possible for all of the R&D project types. However, the analysis of the findings revealed that market-driven forms of resource allocation are most often applied for Type 3 projects, followed by Type 2- and Type 1 projects.

These differences were explained by the characteristics of the different project types and the respective organisational arrangements. The research findings illustrated that the application of market-driven forms of resource allocation is particularly possible if the R&D projects are characterised by a high degree of routine, a high degree of certainty, and a high potential for short-term commercialisation. Moreover, the application of market-driven forms of resource allocation is facilitated by a high degree of decentralisation concerning the determination of budget, the project selection, and the implementation of projects.

Figure 50 illustrates the explored relationships on the example of the project characteristic ‘time-to-market’ and the organisational feature ‘project selection’.



**Figure 50: Possibility to apply market-driven forms of resource allocation**

Given the project type-specific differences mentioned above it was concluded that the application of market-driven forms of resource allocation is particularly possible for Type 3- and Type 2 projects, followed by Type 1 projects.

Moreover, the identified project type-specific differences mentioned above were also crucial for answering the third research question, which was:

*RQ3: For which types of R&D projects are market-driven forms of resource allocation more effective and/or efficient than hierarchical forms of resource allocation?*

The research findings showed that Type 3- and Type 2 projects are compared to Type 1 projects characterised by a higher effectiveness of direct assignments and a higher efficiency of market-driven forms of resource allocation in terms of an improved adaptability to changes in the environment.

Based on the theoretical and empirical findings these differences were explained by the characteristics of the different project types, the respective organisational arrangements, and the applied form of resource allocation.

With regard to the characteristics of R&D projects, it was pointed out that market-driven forms of resource allocation are favourable if the projects are characterised by a high potential for short-term commercialisation (low time-to-market), a high degree of routine, and a high degree of certainty.

Concerning the project type-specific organisational arrangements, it was stated that a high degree of decentralisation concerning the determination of budget, the project selection and the implementation of projects has positive effects on the allocation result of market-driven forms of resource allocation.

Furthermore, it was shown that the applied form of resource allocation has major implications on the allocation result. It was argued that the favourability of market-driven forms of resource allocation strongly depends on the direct interaction between suppliers and requestors, without interference of centralised decision-committees. As illustrated above, a strong interaction of supply and demand normally goes hand in hand with a high share of projects that is initiated by the requesting units and a high financing share of the requesting divisions and/or business units.

Given these conditions, it was concluded that market-driven forms of resource allocation are most effective and efficient for Type 3- and Type 2 projects, followed by Type 1 projects.

The research results presented above were finally validated and verified by practitioners. Therefore, a set of group interviews was conducted. The interviewed R&D experts unanimously confirmed the previous findings and added valuable knowledge and insights to this study (e.g. intranet-based architecture for the establishment of internal R&D markets). In this way the group interviews made signifi-

cant contributions to the derived policy recommendations, which are presented in the subsequent section.

On the basis of the theoretical studies and the conducted methods-triangulation, including case study research, survey research and group interviews, it can be concluded that the establishment of internal R&D markets involve several advantages, but also some disadvantages. The major advantages can be summarised as follows:

- increased internal competition provides incentives and stimulates motivation and performance;
- increased transparency concerning the R&D activities and the associated costs;
- increased closeness to customers leads to a better understanding of explicit and implicit customer needs;
- transactions are facilitated since the market determines the real cost and value of traded goods and/or services;
- increased flexibility and faster response to market changes;
- rapid adjustments to changing conditions;
- improved decision quality by more strongly capitalising upon decentralised information;
- ranking of R&D projects according to market needs;
- short and direct communication procedures reduce information asymmetries, opportunistic behaviour and most important time-to-market.

These advantages illustrate that internal R&D markets can help to overcome the weaknesses of traditional hierarchical structures, since they are characterised by short communication and decision procedures and thus contribute to the reduction of information asymmetries. Additionally, they sanction opportunistic behaviour with loss of trust.

Likewise, the establishment of internal markets leads to a heightened cost-consciousness and thus to an increased productivity and efficiency. Due to the high degree of decentralisation, the top-management is no longer engaged too strongly in the operative business and can concentrate more effectively on strategic tasks.

However, the establishment of internal R&D markets also holds some disadvantages that need to be considered. The major disadvantages can be summarised as follows:

- establishment and design of internal R&D markets possibly require high levels of investments (e.g. in adequate IT infrastructure);
- danger that sensible information and knowledge flow out to unauthorised third parties;
- disclosure of confidential data;
- high administrative efforts for the definition of security levels;
- in tendency neglect of strategically important projects, since market participants often focus too strongly on short- to medium-term financial goals.

Given the mentioned advantages and disadvantages of internal R&D markets, companies have to weigh up if the chances outweigh the risks. In case the answer is yes, the following section provides valuable information for the establishment and design of internal R&D markets in form of policy recommendations.

## 7.2 Policy recommendations

Based on the findings of the literature review (chapter 2), the case study research (chapter 4), the survey research (chapter 5), and the group interviews (chapter 6), finally, policy recommendations for the design of internal R&D markets were derived. These recommendations provide a sound base for answering the fourth research question, which was:

*RQ4: How should an internal market within R&D be designed?*

On the basis of the project characteristics and the organisational arrangements, in a first step, guidelines for the application of internal R&D markets are developed. In this way it is possible to decide for which projects a market-driven resource allocation is basically possible. Thereafter, potential designs of R&D markets are illustrated and discussed. In order to support the decision-maker to find the most suitable allocation design, eventually, a model for the evaluation of alternative forms of resource allocation is introduced. Finally, the single stages for the establishment and design of internal R&D markets are summarised.

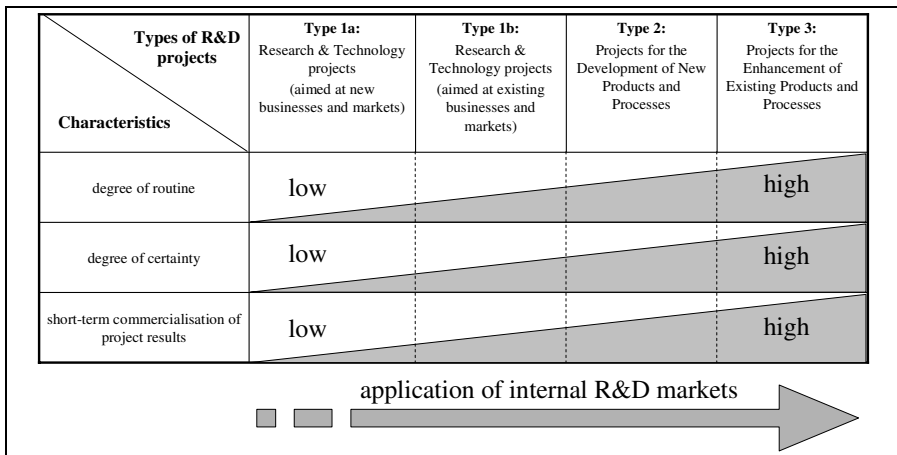
In a first step, it should be illustrated under which conditions the application of internal R&D markets is possible. Based on the conducted theoretical and empirical studies it was proved that different types of R&D projects can be identified on the basis of certain characteristics. According to that the following main project types can be distinguished:

- Research & Technology projects (Type 1),<sup>63</sup>
- Projects for the development of new products and processes (Type 2), and
- Projects for the enhancement of existing products and processes (Type 3).

The conducted studies illustrated that depending on the project characteristics the following general statements can be made concerning the application of internal R&D markets:

- The lower the degree of innovation, respectively, the higher the degree of routine of the respective project, the more likely is the application of market-driven forms of resource allocation.
- The lower the degree of uncertainty, respectively, the higher the degree of certainty, the more likely is the application of market-driven forms of resource allocation.
- The lower the time-to-market, respectively, the higher the potential for short-term commercialisation of the project results, the more likely is the application of market-driven forms of resource allocation.

Concerning the created typology of R&D projects, these premises are mostly fulfilled for Type 3 projects, followed by Type 2 projects and Type 1 projects. This leads to the following guidelines that are illustrated in Table 35.



**Table 35: Guidelines for the application of internal R&D markets in dependence on project characteristics**

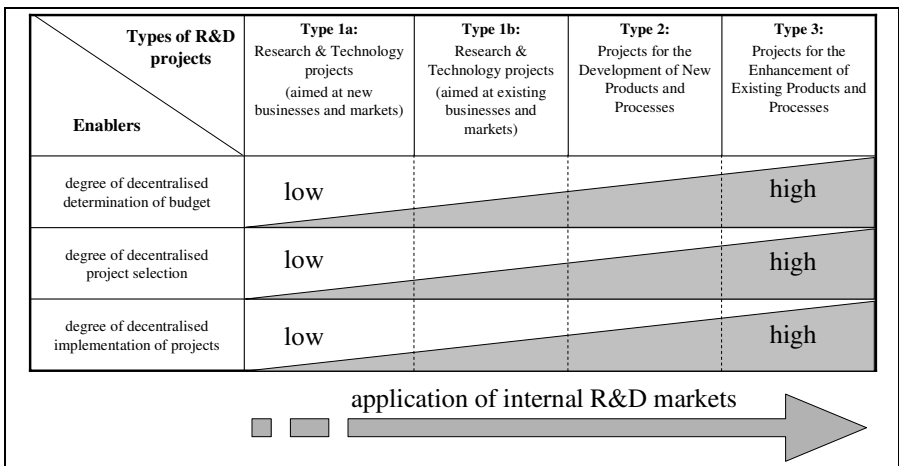
<sup>63</sup> According to the conducted case studies Type 1 projects can be subdivided into two groups. On the one hand the R&T projects that aim at new businesses and markets (Type 1a) and on the other hand the R&T projects that aim at existing businesses and markets (Type 1b).

Table 35 reflects the following general guidelines: The application of internal R&D markets is particularly possible for Type 3 projects, followed by Type 2- and Type 1 projects. Especially difficult is the application of market-driven forms of resource allocation for Research and Technology projects that aim at new businesses and markets (Type 1a).

The conducted studies made clear that also the organisational conditions (enablers) must be taken into consideration, in addition to the project characteristics mentioned above. It can be summarised that depending on the organisational arrangements the following general statements can be made concerning the application of internal R&D markets:

- The higher the degree of decentralisation concerning the determination of budget, the more likely is the application of market-driven forms of resource allocation.
- The higher the degree of decentralisation concerning the project selection, the more likely is the application of market-driven forms of resource allocation.
- The higher the degree of decentralisation concerning the implementation of projects, the more likely is the application of market-driven forms of resource allocation.

Concerning the created typology of R&D projects, these premises are mostly fulfilled for Type 3 projects, followed by Type 2 projects and Type 1 projects. This leads to the following guidelines that are illustrated in Table 36.



**Table 36: Guidelines for the application of internal R&D markets in dependence on the organisational conditions (enablers)**

Table 36 reflects the following general guidelines: The application of internal R&D markets is particularly possible for Type 3 projects, followed by Type 2- and

Type 1 projects. Especially difficult is the application of market-driven forms of resource allocation for Research and Technology projects that aim at new businesses and markets (Type 1a).

In summary it can be said that the decision if the application of internal R&D markets is generally possible depends on the project characteristics on the one hand and the organisational conditions (enablers) on the other hand. Therefore, the project characteristics and the organisational conditions (enablers) must be brought together, in order to make an overall evaluation of the possibilities to apply internal R&D markets. Figure 51 shows the developed model, which indicates if the application of internal R&D markets is suitable or not.

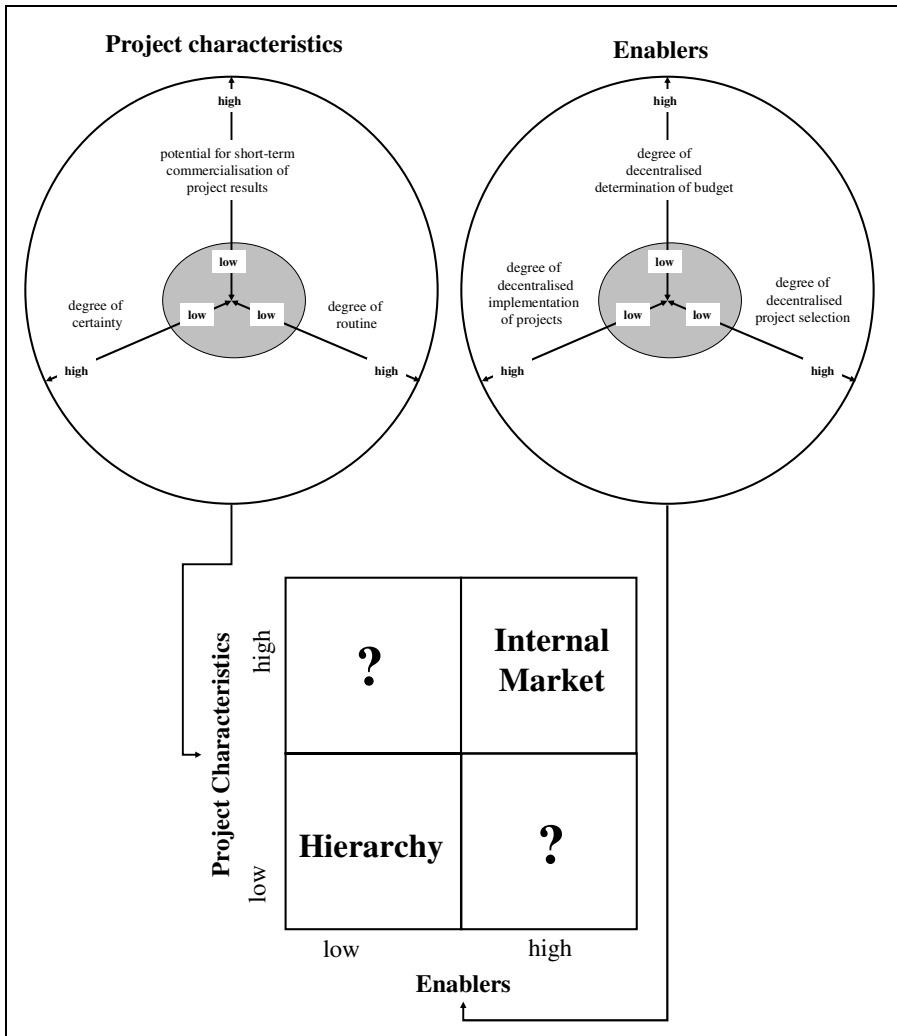


Figure 51: Model for the evaluation of the possibility to apply internal R&D markets

Through the combination of the project characteristics and the enablers in a portfolio the following four situations are conceivable, in principle:

- Both the characteristic features of the project characteristics and the enablers are rather high; this means that the application of internal R&D markets is rather possible.
- Both the characteristic features of the project characteristics and the enablers are rather low; this means that the application of internal R&D markets is rather not possible.
- The characteristic features of the project characteristics are rather high, whereas the characteristic features of the enablers are rather low; this means it has to be examined if it is possible to usefully influence the enablers. For example, by means of a more decentralised organisation of the R&D activities by which the application of internal R&D markets would be enabled.
- The characteristic features of the project characteristics are rather low, whereas the characteristic features of the enablers are rather high; this means it has to be examined if it is in spite of the project characteristics possible and useful to apply internal R&D markets.

On the basis of the decision model presented above a decision-maker can decide whether the application of market-driven forms of resource allocation is possible or not. But how should internal R&D markets be designed?

As the conducted studies illustrated, neither the 'pure' form of hierarchy nor the 'pure' form of an internal market exist in practice. Rather the R&D resource allocation often consists of a mix of hierarchical and market elements (see section 4.4).

Therefore, in Table 37, the elements of internal R&D markets are compared with the corresponding elements of a hierarchy. The presented elements stem from the conceptual framework, which was presented in section 3.2.

Hierarchy	versus	Internal Market
Existence of several actors (Providers / Users)	○-----●	Existence of several market actors (Suppliers / Requestors)
No competition; the fulfilment of initial plans is directly monitored by a central decision-maker or decision-committee	○-----●	Competition; regulated by means of market supervisors in order to prevent misuse of market power and to intervene in disputes
The specific features of the goods and services and thus the resources are determined by a decision-maker or a decision-committee. No direct interaction between providers and users.	○-----●	Different resources are the condition for exchange relationships between the actors. The specific features of the goods and services are negotiated by the direct interaction of supply and demand.
Actors are hierarchically dependent on higher authorities	○-----●	Actors are hierarchically independent
The hierarchical transactions are predetermined by a central decision-maker or decision-committee	○-----●	Actors process transactions via adequate infrastructures (e.g. initiate projects via an intranet-based marketing; this means that the Intranet serves as a market place)
Actors have to act according to the instructions of the higher authorities	○-----●	Actors transact according to their individual preferences
No existence of prices and/or settlement of prices that are predetermined by a central decision-maker or decision-committee	○-----●	Existence of negotiated prices; this means that the requestor has to pay a price to the supplier in return for the received good or service
Existence of transaction objects; the nature and quantity of the transaction objects is predetermined by a central decision-maker or decision-committee	○-----●	Existence of transaction objects; the nature and quantity of the transaction objects is negotiated by the direct interaction of supply and demand
Actors have no right to appropriate profits; profits are transferred to the company (cost center organisation)	○-----●	Actors have the right to appropriate profits due to negotiated contracts (profit center organisation)

○ actual state      ● targeted state

**Table 37: Hierarchy vs. Internal Market**

With regard to each element shown in Table 37, a multitude of design possibilities are conceivable. For example, concerning the actors it can be decided whether external suppliers and/or requestors are admitted or excluded from such an internal R&D market.

The number of market participants in turn has corresponding implications on the intensity of competition in an internal R&D market.

Likewise, the actors can be equipped with different resources and also a stronger hierarchical independency of the respective actors can be supported.

Moreover, for the settlement of market-driven transactions efficient infrastructure is required (e.g. creation of a R&D portal in the Intranet).

Depending on the design of the internal R&D market the actors can also be allowed to make independent decisions according to their own preferences (value maximisation).

A further important design element is the pricing system for the settlement of conducted transactions. In this context the ‘designer’ can choose from a wide-range of possibilities, such as settlement of fixed transfer prices, settlement of negotiated prices or settlement of market prices. In this context the design of an adequate auction model can be beneficial in order to facilitate the negotiation processes (refer to the conceptual framework presented in section 3.2).

The transaction objects in an internal R&D market are the respective intellectual property, ideas, R&D projects and/or services, and R&D results. The nature and quantity of these transaction objects is also negotiated by the direct interaction of supply and demand.

The conducted transactions in an internal R&D market are based on contracts or so-called service level agreements that determine all the relevant conditions of the respective transactions and allow the actors to fully appropriate the profits that can be obtained from these transactions.

The remarks made above give the potential ‘designer’ (e.g. management board) of an internal R&D market a clue which elements can be designed, in principle. However, the decision-makers have to bear in mind that for each element numerous designs are basically conceivable (for further explanations refer to the conceptual framework presented in section 3.2). In this context one has to be aware of the fact that there is not only one universally ‘correct’ design. Rather there exist a multitude of potential designs, and which of them is preferable clearly depends on the company-specific circumstances.

Thus, it is advisable to start with determining the current state of R&D resource allocation. On this basis one or several targeted states concerning the design of an internal R&D market can be defined. Subsequently, the alternative design elements must be evaluated concerning their favourability. In general, the favourability of alternative forms of resource allocation can be measured on the basis of the criteria effectiveness and efficiency.

The criterion effectiveness is concerned with answering the question to what extent the chosen form of allocation leads to the fact that the ‘right’ R&D projects are selected and implemented (‘doing the right things’).<sup>64</sup>

On the other hand the criterion efficiency is concerned with answering the question to what extent the resource allocation process itself is conducted in the right way (‘doing the things right’).<sup>65</sup>

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<sup>64</sup> Effectiveness criteria can be: (1) increase in the company’s value (compared with the stock quote or the market capitalisation), (2) value contribution of a project (compared with the net present value), (3) innovation rate (compared with turnover by new products in relation to total turnover) etc.

<sup>65</sup> Efficiency criteria can be: (1) improved adaptability to changes in the environment and thus more flexible resource control, (2) more precise estimation of costs, (3) shortening of the resource allocation process, (4) reduction of allocation costs etc.

For the measurement of effectiveness and efficiency there are a multitude of criteria available. In the R&D field often the net present value method for the calculation of the value contribution of the respective projects is applied in order to measure the effectiveness (Völker & Kasper, 2002). However, the efficiency is often measured on the basis of the criteria quality, time and costs (Völker, 2000).

Beside the criteria effectiveness and efficiency also secondary effects must be taken into consideration when deciding upon alternative forms of resource allocation. For example, the switch from hierarchical forms of resource allocation to market-driven forms of resource allocation can possibly lead to an increased transparency and/or a stronger interaction between the involved parties. This again can lead to the generation of additional ideas and project proposals and to the fact that synergies are identified earlier and thus are used more consequently (positive secondary effects). However, the increased transparency can also increase the danger that valuable knowledge flows out to unauthorised third parties, e.g. competitors (negative secondary effects).

Basically, there are two general possibilities to compare alternative forms of resource allocation. On the one hand the favourability can be measured on the basis of a scoring approach; on the other hand the evaluation can take place in monetary terms by applying a value-oriented approach (DeltaNPV). Within the scope of the policy recommendations a combination of both approaches is proposed.

Table 38 illustrates the developed model for the evaluation of alternative forms of resource allocation.

Alternative Allocation Forms		Evaluation Criteria																				
Actual State vs. Targeted State		Effectiveness					Efficiency					Secondary Effects										
Elements of the Actual State	Elements of the Targeted State (Market Elements)	-3	-2	-1	0	+1	+2	+3	-3	-2	-1	0	+1	+2	+3	-3	-2	-1	0	+1	+2	+3
Actual Element 1	Targeted Element 1																					
Actual Element 2	Targeted Element 2																					
...	...																					
Actual Element n	Targeted Element n																					

**Table 38: Evaluation of the favourability of alternative forms of resource allocation**

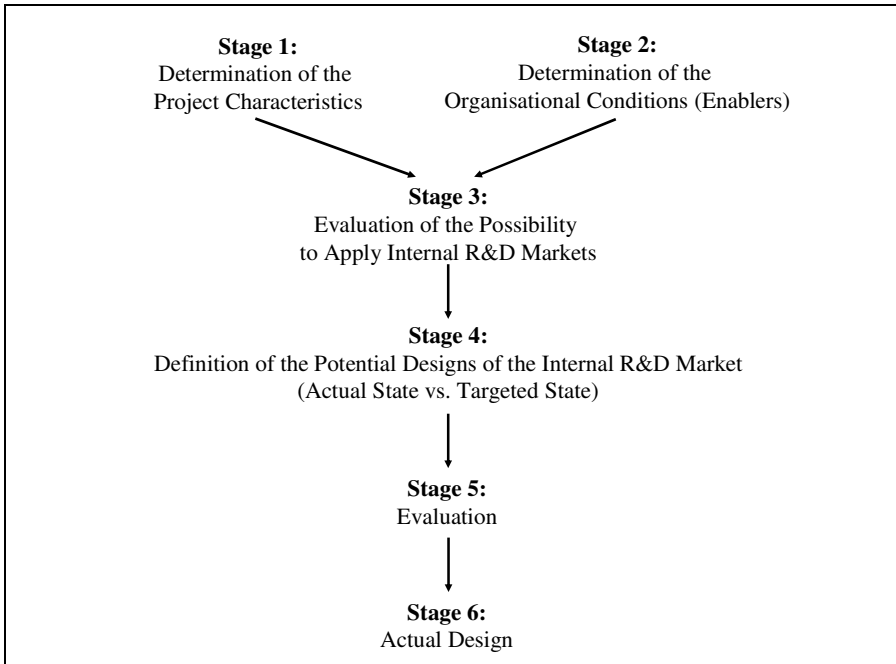
In a first step, the actual elements of the resource allocation process are confronted with the targeted (market) elements. The actual elements represent the actual state of the resource allocation and are thus evaluated with ‘zero’. In the example presented above the evaluation of the targeted elements occurs on a scale with seven response categories (from -3 to +3), which are linked to monetary values (e.g. +1 = <0.1 million € Δ NPV; +2 = <1 million € Δ NPV; +3 = <5 million € Δ NPV). On this basis the alternative elements can be evaluated concerning the criteria effectiveness, efficiency and secondary effects.

Based on this sophisticated evaluation model, in a final step, it can be decided how the internal R&D market should actually be designed.

According to the remarks made above the developed recommendation model can be subdivided into the following 6 stages:

- Stage 1 is concerned with the determination of the characteristics of the respective R&D projects.
- In stage 2 it is important to examine the prevailing organisational conditions (enablers).
- Thereafter, in stage 3, the project characteristics and the enablers are combined in a portfolio in order to decide if the application of internal R&D markets is generally possible.
- In case the application of internal R&D markets is generally possible, in the subsequent stage 4, the actual state as well as one or several potential targeted states concerning the R&D resource allocation must be defined.
- In stage 5, based on the evaluation model, it can be investigated which form of resource allocation is most suitable.
- Finally, in stage 6, the actual internal R&D market design can be determined.

Figure 52 shows the single stages of the developed recommendation model for the establishment of internal R&D markets in an overview.



**Figure 52: Recommendation model for the establishment of internal R&D markets**

The recommendation model presented above gives crucial support for answering the set up research questions. Firstly, it shows if and under which circumstances a market-driven resource allocation is generally possible. Furthermore, it shows under which conditions market-driven forms of resource allocation are more effective and/or efficient, in comparison to hierarchical forms of resource allocation. Thus, on the basis of this model concrete recommendations can be given on how to design an internal R&D market.

### 7.3 Critical appraisal

First of all a general comment: The reader of this work has to be aware that the presented data were raised at a certain point of time under certain circumstances. These circumstances may have changed in the meantime. This means that this work represents findings and conclusions that appeared to be true at the time the research was conducted, but in future things may be different.

As mentioned in the methodology chapter, a mixed-method approach appeared to be most appropriate for the present investigation. Since this work had a very exploratory character it was started with an extensive case study research. This was needed as a preparatory stage before embarking on a questionnaire. However, the exploratory character also had implications on the analysis of the survey data. This means that the raised quantitative data were mainly used for descriptive purposes and aimed at exploring basic relationships within the scope of internal R&D markets. The research findings were then validated and verified by conducting a set of group interviews with practitioners so that it can be concluded that the results presented in this thesis provide a sound basis for future research activities in this area. (How future research might proceed and how other researchers may capitalise upon, respectively, further develop the presented work is discussed further below.)

With regard to the employed research methods, there were several limitations to be aware of (see section 3.9). In the context of the qualitative research the notion of trustworthiness had main emphasis, which aims at supporting the argument that the inquiry's findings are "*worth paying attention to*" (Lincoln & Guba, 1985 p.290). Therefore, the author employed a number of techniques that helped increasing the credibility, transferability, dependability and confirmability of the study and thereby increasing the validity and reliability of the study's findings. These techniques were illustrated in section 3.9. In this context it was also explained why the analysis of the raised qualitative data was done without using software packages.

Moreover, it has to be noted that the conducted qualitative research was based on relatively small samples that may not be representative of the entire population. Moreover, the research was strongly dependent on the cooperation of the interview partners. Without their accurate and complete answers the entire research project wouldn't have been possible. However, in some cases also problems occurred due to aspects of nondisclosure, so that it was difficult to receive all the

required data. Furthermore, in spite of the formulation of a conceptual framework, it cannot be precluded that the participants had divergent interpretations of the term 'internal R&D market'. And, it has to be stated that the participants often had different backgrounds and positions and answered the posed questions from their own 'world view'.

The methodological limitations associated with the quantitative survey research mainly resulted from the relatively small sample. In this context the reader has to be aware that the margin of error is higher for small-sample surveys, and therefore the results are less projectable for surveys with smaller samples (Zikmund, 2002). Regarding the questionnaire itself it cannot be precluded that, even if the translation process was conducted properly, some questions may have posed conceptual problems and other difficulties for respondents (Carrasco, 2003).

A more general limitation of the present investigation resulted from the fact that it cannot be precluded that Type I and Type II errors have been made. For example, Type I errors occur when it is concluded that there is a relationship between variables when in reality there is none. Type II errors involve the opposite occurring, i.e. when it is concluded that there is no relationship between variables when in reality there is one.

As discussed in section 3.9, the reader also has to be aware that the results and conclusions of the survey were solely based on descriptive and bivariate analyses. A more sophisticated statistical approach (multivariate analysis) was not taken. This decision implied that it was not possible to control for 'ceteris paribus' conditions. However, given the fact that the conducted research has to be seen from an 'Industrial Organisation' perspective rather than from an 'Industrial Economics' perspective, a bivariate approach appeared to be most appropriate. In this way it was possible to explore basic relationships between the investigated variables (e.g. between the project types and the applied form of resource allocation), which was the major aim of this thesis. Nevertheless, the application of binomial (binary) logistic regression models, respectively, multinomial logistic regression models could have revealed additional valuable information, as outlined in section 5.6.

Further limitations resulted from the fact that this investigation is the first one that is concerned with the establishment and design of 'real' internal R&D markets and that there are only a limited number of related studies published in peer reviewed journals. Moreover, the studies were difficult to compare as different variables were covered, different methods of analysis were used and often very different industries were studied.

Given the exploratory character of the study, the small sample size and the methodological limitations mentioned above, the reader has to be aware that the research results presented in this thesis are at best indicative. This means that the study describes some basic relationships that are fundamental for the establishment of internal R&D markets. Moreover, the reader has to bear in mind that the methodological limitations limit the credibility of the findings and restrict the population to which findings can be applied. Nevertheless, this work has made

substantial scientific contributions to the research areas ‘innovation management’ and ‘R&D management,’ which are outlined now.

First of all some general remarks concerning the research topic: From the author’s point of view internal markets hold an enormous potential for companies as well as for the whole society. This is particularly true for R&D activities, as evidenced during the course of the presented studies.

Due to the fact that in many companies a trend towards a stronger decentralisation of R&D activities is identifiable, which again implies a stronger organisational market-orientation of internal processes, it can be assumed that the topic ‘internal R&D markets’ will play an increasingly important role in the next years, both in theory and in practice.

Therefore, the research results summarised in this chapter present valuable information for the scientific community as well as for the R&D practice. As the literature review and the case studies showed, the topic ‘internal R&D markets’ was still unexplored. On the one hand there was almost no literature available regarding internal R&D markets. On the other hand the case study research illustrated that most of the investigated companies coordinate their R&D activities by rather hierarchical, administrative structures. The application of market-like elements or internal market mechanisms, however, was only found in a few cases. These facts highlight the novelty of the presented research findings.

Moreover, the development and test of a new taxonomy of R&D projects built a major aspect of the present investigation. In the centre of attention were the following three project types:

- Research & Technology projects (Type 1)
- Projects for the Development of New Products and Processes (Type 2)
- Projects for the Enhancement of Existing Products and Processes (Type 3)

This study revealed some interesting project type-specific differences concerning the project characteristics, the R&D organisation, the R&D resource allocation and the allocation result. Furthermore, the developed taxonomy was tested for the first time within the scope of an international survey.

In addition, the thesis in hand made principal contributions to the state of the art of R&D resource allocation and generated new insights. Based on the reference model ‘external markets’ a new definition of an internal R&D market was formulated. This reference model seemed to be adequate for the inquiry since the creation of internal markets can be seen as the attempt to reconstruct elements of external markets inside a company (Lehmann, 2002).

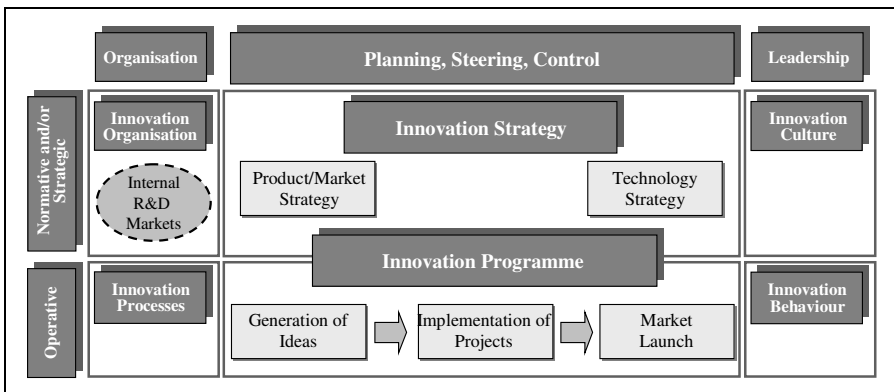
In contrast to the existing literature concerning ‘internal R&D markets’ (see Reger, 1999), the thesis distinguished between research activities on the one hand and development activities on the other hand. Moreover, based on the newly developed project typology, the thesis illustrated project type-specific differences. On this basis it was shown for which types of R&D projects the application of

market-driven forms of resource allocation is possible and preferable. Compared to the relevant literature in this area, which was presented in the literature review, this approach was advanced.

Eventually, a methods-triangulation, including case study research, survey research and group interviews, generated novel research findings that complemented one another. On this basis policy recommendations for the design of internal R&D markets were derived. In this context a sophisticated model for the evaluation of alternative forms of resource allocation was developed. On the one hand this model allows companies to evaluate if and for which R&D projects an internal market can be used for the resource allocation in R&D. On the other hand the developed model indicates for which R&D projects a market-driven resource allocation is more effective and/or efficient than a hierarchical one. In this way the most adequate and efficient allocation design can be selected.

In summary, the novel insights of this inquiry closed the identified research ‘lacunae’ concerning the topic ‘internal R&D markets’. Moreover, the conducted research provides new scientific contributions to the state of the art of R&D resource allocation and gives helpful recommendations for practitioners. Last but not least, it constitutes the basis for future research activities in this area. Some potential directions as to how future research might proceed are outlined now.

Before this work was undertaken the topic ‘internal R&D markets’ was a largely unexplored organisational concept. This again illustrates the exploratory character of the conducted research and makes clear that the present investigation lays the foundation for further research in this area. In this context it is of particular interest how the organisational concept ‘internal R&D market’ can be usefully integrated within the already existing elements of innovation management, which are shown in Figure 53.



**Figure 53: Elements of innovation management**

In accordance with the 'St. Galler Management Model' (Bleicher, 1990), Figure 53 shows that initially an innovation strategy is needed within the scope of a comprehensive innovation management. This strategy is based on two pillars. On the one hand the product/market strategy and on the other hand the technology strategy. Within the strategic framework an efficient operative innovation process should run, from the generation of ideas, via the implementation of projects up to the market launch. Likewise important is a systematic procedure concerning the planning, steering and control of the innovation programme as well as the establishment of an adequate innovation culture and a corresponding innovation-oriented behaviour of the management and the co-workers. As illustrated in Figure 53, organisational structures and consequently organisational concepts, such as 'internal R&D markets' also play an important role for an effective and efficient innovation management.

On this basis the following further research question can be formulated:

- How can the organisational concept 'internal R&D market' be integrated within existing leadership systems and/or innovation cultures?

The close coordination between organisation, leadership and culture is not only of great importance in the innovation context (Von Krogh, Ichijo & Nonaka, 2000). Without such coordination with the pillars leadership and culture organisational concepts are less promising.

In addition to the future research field explained above the following further research questions resulted during the course of this study:

- How can the organisational concept 'internal R&D market' usefully be combined with already existing external R&D networks and/or external R&D markets?
- How can auction-based internal R&D markets be usefully implemented?
- How should adequate incentive systems be designed within the scope of internal R&D markets?

For answering these questions other researchers can capitalise upon, respectively, develop further the presented work and thus use it as a base for their own research. In addition, the conducted studies have also some policy relevance. Nowadays there is an ongoing discussion about the pros and cons of outsourcing. Many companies shift their production and the associated jobs to emerging countries, such as China. Most of these jobs are concerned with mass production. But, in times of knowledge society, the outsourcing efforts of companies are no longer restricted to 'low technology jobs'. More and more 'qualified' jobs are going to be shift to low cost countries, e.g. software development in India.

In this context, internal markets will play an increasingly important role in future, not least in R&D contexts. In the long run it is conceivable that R&D functions of companies will be mainly substituted by smaller decentralised local R&D labs that interact via networks. Projects and services are directly assigned or requested via electronic platforms (e.g. Intranet) and prices are negotiated between suppliers and requestors (e.g. auction). Eventually, a certain project or service is assigned to that R&D lab that provides the requested service at the lowest costs.

In consequence, this could lead to an improved innovation rate and positive effects on the competitiveness and profitability of companies. However, this could also lead to an increased shift of 'qualified' jobs from industrialised countries to emerging countries. This in turn would increase the prosperity of 'poorer' countries and would lead to a more fairly shared income worldwide. This would further imply an increased average purchasing power of the consumers and an increased demand for goods and services. This increased demand in turn would create new jobs worldwide and could contribute to the reduction of unemployment. As a result, the welfare of the whole society would increase.

The scenario described above may sound a bit visionary, but it at least indicates the tremendous potential of the flexible organisational concept 'internal market'.

In conclusion, the novel research findings which are presented in this thesis lay the foundation for the establishment and further development of internal R&D markets. Therefore, the results of this study have made principal contributions to the literature on innovation management, respectively, R&D management. Moreover, the research results can be transferred to other corporate functions and thus enable the creation of further internal markets. As a consequence, this organisational transition should lead to an increased effectiveness and efficiency of corporate activities. In this way the stronger market-orientation of internal resource allocation processes should strengthen the competitiveness of companies in highly competitive world markets.

# Appendix 1 – Case studies

## Interview guide

The implementation of the case studies was oriented on the subsequently shown interview guide. Afterwards the most interesting aspects of the respective case studies are illustrated, according to the following basic structure:

### **A) General questions concerning the company**

- What are the key features of your company (company, revenue, cash flow, number of co-workers, R&D quota, Industry etc.)?
- Which products/services are offered by your company?
- Which are the most important markets/products?

### **B) Questions concerning the R&D projects and the R&D project types**

- Which specific characteristic features describe R&D projects?
- Is there a project categorisation in your company, respectively, which R&D project types can be usefully distinguished?
- Based on which criteria can these project types be differentiated from each other?
- How much is the R&D budget for the respective project types?
- How many projects are currently conducted for each project type?

### **C) Questions concerning the R&D organisation**

- How does your organisation look like?
- How are the tasks distributed concerning your R&D activities?
- Which R&D units exist within your company?
- How are the R&D activities integrated within the other company functions (production, marketing, sales etc.)?
- Are your R&D units profit responsible (cost center vs. profit center)?
- How are the R&D budgets determined (top-down vs. bottom-up)?
- Where are the respective project types selected from an organisational point of view?
- Where are the respective project types implemented from an organisational point of view?

- How is your innovation process organised?
- Do you cooperate with any partners within your innovation process?

**D) Questions concerning the R&D resource allocation**

- How are your resource allocation processes organised concerning the respective project types?
- Who initiates ideas and/or projects?
- Who decides if a project is included in the company's project portfolio?
- How is the decision concerning the project selection organised exactly?
- Who makes decisions concerning the reallocation of resources during the project implementation?
- On which criteria are the allocation decisions based?
- How do other functions, such as controlling, support the resource allocation processes?

**E) Questions concerning potential starting points for the interaction of supply and demand**

- Do you think that ideas/projects can be implemented by the direct interaction of supply and demand?
- Where do you see potential starting points for the application of a market-driven resource allocation, respectively, of an internal R&D market?
- Who are the potential suppliers and requestors in such a market?

## **ABB**

State: 2002

### **A) Key features of the company**

ABB is a leader in power and automation technologies that enable utility and industry customers to improve performance while lowering environmental impact. The ABB Group of companies operates in around 100 countries and employs around 160,000 people. In the financial year 2000 the group achieved total revenues of almost 24 billion US\$. Approximately 3% of the revenues were spent for R&D activities. About 15% of the R&D expenditures were used for research activities in the central research unit. Worldwide nearly 6000 scientists and technology experts work in the group's divisions and the respective R&D labs. The ABB organisation comprises the following four divisions: Process industries & Automation, Utilities, Production & Consumer goods, and Oil, Gas & Petrochemistry. Each division consists of several business units that are present in different countries. Currently the R&D capacities in the US and in Asia are rather extended, whereas the R&D capacities in Europe are rather reduced.

### **B) R&D projects**

The R&D efforts of ABB comprise the order-related development, which is financed by customers, the product and system development in the divisions and/or business units as well as the actual research activities of the central research unit. The company distinguishes the following types of R&D projects:

- Fuzzy Front End projects (basic research) (10 million US\$ p.a.)
- Projects for the development of technology platforms (100 million US\$ p.a.)
- Product development projects (600 million US\$ p.a.)
- Contract development projects (900 million US\$ p.a.)

The so-called Fuzzy Front End activities comprise basic research in fields, in which the company has only little or no knowledge. Correspondingly, there are no concrete fields of application defined at the beginning of such projects. These activities as well as the technology platform development are conducted by the central research unit. However, the product development and the order-related development take place in the decentralised divisions and/or business units.

### **C) R&D organisation**

The research units have the task to lay the foundations for the subsequent product development in the divisions and business units. In the four global ABB research labs work approximately 800 researchers and in the eight research centers work additionally 1200 researchers. The four research labs of the group coordinate the activities of the research centers within the scope of so-called corporate research programmes. Furthermore, within this network there is a close cooperation with external partners, such as universities. Each of the research centers represents a certain expertise in different technology fields. Thus, this expertise is available and can be used in both the research units and the development units of the respective divisions and business units.

The organisational integration of the R&D activities within the other functions of the ABB group takes place via so-called Strategic Technology Teams (STT) that function as a kind of R&D board for the respective divisions. So, each division has one STT, which consists of the respective Division Technology Manager, the relevant Research Lab Managers as well as further R&D experts from the divisions and business units that are important for the decision-making process. In total the STTs consist of approximately 10 experts, which plan the R&D activities in the R&D labs and the corresponding divisions. In this way the activities of the central research labs are more strongly linked to the needs of the divisions that are close to markets and customers. The STTs are mainly concerned with the following questions: What should be done? Where should it be done? Which resources should be invested? How much time is required for a certain programme and/or project? Which is the adequate project organisation for the implementation of the tasks?

The STTs are also responsible for the Strategic Technology Planning (STP), which is conducted at least two times a year for each competence field (energy, automation etc.). Included in this planning procedure is also a so-called Technology Screening, which deals with the following questions: How are our competitors positioned in a certain research field? How should we position in this field? Where are potential research gaps? What is state-of-the-art and what are our competitors and/or non-competitors undertaking? The result of the Strategic Technology Planning is the so-called Strategic Technology Action Plan, in which all the further steps concerning the respective competence field are defined.

### **D) R&D resource allocation**

The organisation of ABB's R&D resource allocation follows a so-called Stage Gate Process. The ABB Gate Model distinguishes three Model Types in accordance to the following categories of R&D projects: (1) Technology Development projects (TD), Product Development projects (PD), and Process Improvement projects (PI). Furthermore, the model consists of eight clearly defined gates, at which the respective projects are evaluated from an economical point of view.

The following gates are involved in this resource allocation process:

- Gate 0: Agreement to start a project
- Gate 1: Agreement on project scope
- Gate 2: Agreement on requirements
- Gate 3: Agreement on design
- Gate 4: Agreement on product readiness for piloting
- Gate 5: Agreement on Product/Solution Release
- Gate 6: TD/PD: Close project; PI: Finalise implementation according to scope
- Gate 7: Follow-up on project results and benefits delivery

At each of these gates the members of the project team must answer numerous questions, which are listed in Table 39.

Gate	Questions that must be answered at the respective gates
0	<ul style="list-style-type: none"> <li>- Is the opportunity in line with the overall business strategy and will it create acceptable value?</li> <li>- Are other alternatives evaluated, and why have they not been selected?</li> <li>- Has some other party already addressed this opportunity?</li> <li>- Can the organisation afford the investment in the next phase?</li> <li>- Are all resources required for the next phase identified and committed?</li> <li>- Has the duration and resource need for the next phase been defined?</li> <li>- What Model Type of the ABB Gate Model should be applied to this project?</li> </ul>
1	<ul style="list-style-type: none"> <li>- Is the opportunity in line with the overall business strategy and will it create acceptable value?</li> <li>- Are the requirements known well enough to allow planning of the project?</li> <li>- Can the organisation afford the investment in the next phase?</li> <li>- Are all resources required for the next phase identified and committed?</li> </ul>
2	<ul style="list-style-type: none"> <li>- Is there a business case and is the expected value creation acceptable?</li> <li>- Have legal, internal audits, tax and/or export control aspects been analysed?</li> <li>- Are the requirements from US GAAP considered?</li> <li>- Is an overall project plan available and the details for the next phase defined?</li> <li>- Are the project risks identified, acceptable and is a mitigation plan in place?</li> <li>- Has the change impact of the new solution been identified and evaluated?</li> <li>- Is this project consistent with a group approach?</li> <li>- Are all resources required for the next phase identified and committed?</li> <li>- Can the organisation afford the investment in the next phase, and consecutive phases?</li> <li>- Is funding available for the following phase and has commitment for the consecutive phases been made?</li> </ul>

3	<ul style="list-style-type: none"> <li>- Is the business case still valid?</li> <li>- Have legal, internal audits, tax and/or export aspects been analysed?</li> <li>- Is an overall project plan available and are the details for the next phase, including test plan, defined?</li> <li>- Has the change impact of the new solution been reassessed?</li> <li>- Has appropriate communication material been prepared and made available to the defined target audience?</li> <li>- Are all critical design issues specified together with the relevant stakeholders?</li> <li>- Are the project risks reassessed?</li> <li>- Are all resources required for the next phase identified and committed?</li> <li>- Can the organisation afford the investment in the next phase, and consecutive phases?</li> <li>- Is funding available for the following phase and has commitment for the consecutive phases been made?</li> </ul>
4	<ul style="list-style-type: none"> <li>- Is the business case still valid?</li> <li>- Is the solution and organisation ready for pilot use?</li> <li>- Are the project risks reassessed?</li> <li>- Are all resources required for the next phase identified and committed?</li> <li>- Can the organisation afford the investment in the next phase, and consecutive phases?</li> <li>- Is funding available for the following phase and has commitment for the consecutive phases been made?</li> </ul>
5	<ul style="list-style-type: none"> <li>- Has the product/project result been provided to the receiving organisation?</li> <li>- Will the developed solution deliver the value as expected?</li> <li>- Have the metrics for benefit delivery been defined?</li> <li>- Can the solution be operated, supported and maintained by appropriate groups?</li> <li>- Has appropriate communication material been prepared and made available to the defined target audience?</li> <li>- Are all resources required for the next phase identified and committed?</li> <li>- Is funding available for the following phase?</li> </ul>
6	<ul style="list-style-type: none"> <li>- Has the project been executed according to scope?</li> <li>- Has the project execution team been dissolved?</li> <li>- Have the experiences from the project been collected and documented?</li> </ul>
7	<ul style="list-style-type: none"> <li>- Has the developed solution delivered the value as expected?</li> <li>- Have the experiences from the product/project results been collected and documented?</li> </ul>

**Table 39: Questions of the ABB Gate Model**

Through the procedure illustrated above the effectiveness and efficiency of management decisions should be increased, so that the scarce R&D resources are particularly used for those projects that create the highest value contribution to the ABB group.

### **E) Potential starting points for an internal R&D market**

A market-like element that is already applied in ABB's R&D resource allocation processes is the so-called direct assignment. This means that the R&D units are instructed by the divisions and/or business units to implement certain R&D projects. Moreover, the corresponding projects are financed by the requesting units. A further potential market element would be direct offers of R&D units in order to find potential requestors and/or financial backers. In this context the requesting unit, which is willing to pay the highest price, acquires the exclusive marketing and disposition rights. Furthermore, projects and/or project results that don't fit into ABB's project portfolio could be sold or licensed via an external market. (However, this is relatively seldom the case because of the well-organised R&D planning, in which all the relevant parties are involved from the beginning.)

## **Abbott**

State: 2002

### **A) Key features of the company**

Abbott Laboratories is a global, diversified health care company devoted to the discovery, development, manufacture and marketing of pharmaceutical, diagnostic, nutritional and hospital products. The company currently employs approximately 70,000 people and markets its products in more than 130 countries. In March 2001 Abbott Laboratories acquired the BASF Aktiengesellschaft pharmaceuticals division including Knoll AG's worldwide business. This acquisition complements the product and development portfolio in several of Abbott's core franchises, including oncology, cardiovascular, neuroscience/pain and metabolic diseases. In November 2001, Abbott GmbH, Wiesbaden, Knoll GmbH and Knoll Deutschland GmbH, Ludwigshafen were merged to form Abbott GmbH & Co. KG.

Abbott currently has nearly 3,500 employees working at the German sites in Wiesbaden and Ludwigshafen, and offers a wide range of pharmaceutical and diagnostic products – from prevention and diagnosis to treatment and cure. Thanks to substantial investments in discovery science, Abbott has been able to develop innovative medications which lessen the threat of many diseases. The Abbott group achieved total revenues of approximately 16 billion US\$, thereof 1.4 billion were contributed by the German branches. Abbott spent \$1,577,552,000 in 2001 on research to discover and develop, respectively, to improve existing and/or new products and processes. This meant a R&D quota of almost 10%.

## B) R&D projects

The projects of the Abbott project portfolio are categorised according to their innovative contribution. The following types of R&D projects are distinguished:

- Breakthrough-innovation projects
- New product development projects (new molecular entities (NME))
- Line Extensions

As breakthrough-innovation projects can be described such projects that are implemented in order to develop new active substances. Within the scope of NME projects substances with a new chemical structure are developed on the basis of already known active substances. Eventually, line extensions aim at the enhancement of already existing products and/or substances.

## C) R&D organisation

Each active substance has to pass through several stages during its development. The respective stages are subdivided into corresponding activities and milestones. Due to strict regulations the innovation processes of pharmaceutical companies are largely predetermined. According to the International Drug Development System (IDDS) the innovation process at Abbott can be sketched as follows (see Figure 54).

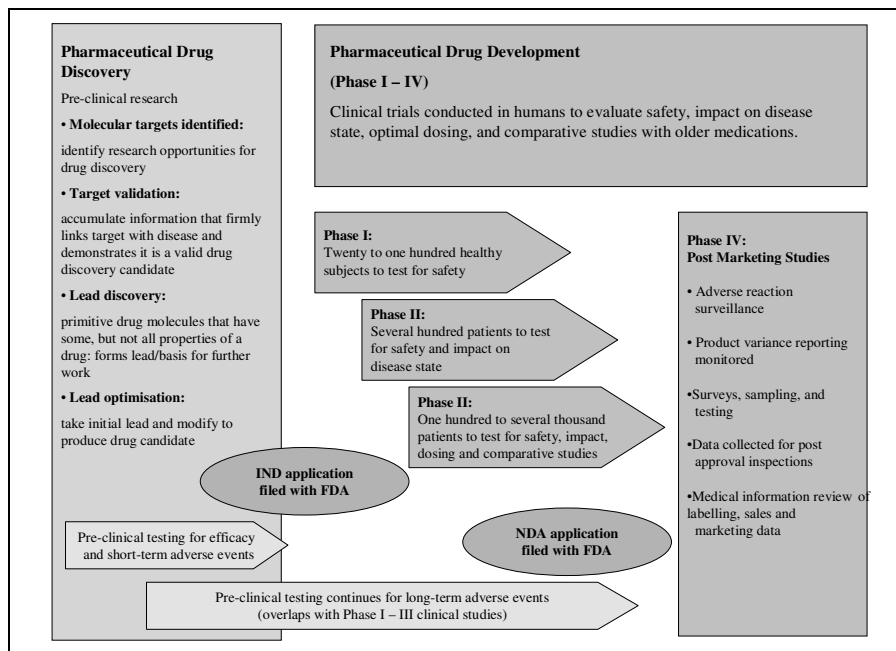


Figure 54: Innovation process at Abbott

Within the context of the innovation process the product target profile (PTP) plays a central role. The PTP is an important result that must be achieved at the end of the 'pre-clinical research stage'. This stage consists of the following four steps: (1) Molecular target identification, (2) Target validation, (3) Lead discovery, and (4) Lead optimisation. After these four steps a new molecular entity and a new PTP for a pharmaceutical product together with a drug development plan and the corresponding business plan must be presented.

All in all it may be said that the PTP serves as a guideline for the subsequent clinical research stages up to the final registration of the respective new substances. At the end of each stage it must be decided if the made progress is in line with the formerly in the PTP determined requirements and milestones. On this basis it is judged if the project is qualified for the next stage. In this context the PTP provides on the one hand details concerning the feasibility (based on scientific insights and experience) of the R&D project; on the other hand it provides information concerning the project's necessity (based on market requirements and official conditions). Thus, the PTP is relevant for all controlling processes along the above-illustrated innovation process as well as for the finally conducted post marketing studies.

#### **D) R&D resource allocation**

The research fields are determined top-down by the Abbott executive committee. The actual budgeting process takes place on a zero-based budgeting basis. From the overall strategy mid-term and long-term goals are defined, from which operative R&D programmes are derived. On this basis budgets are allocated to the corresponding locations (centers of excellence) that are most suitable for the implementation of the respective studies and projects. This top-down budgeting process is complemented by a corresponding bottom-up budgeting process, by which the respective centers of excellence make their project proposals that they wish to conduct within the scope of the determined research programmes.

In a further step, all the project proposals are aggregated and judged by a central steering committee. After the project selection process the corresponding budgets are allocated to the units that execute the studies and projects. The coordination of the respective projects takes place in the responsible decentralised units (centers of excellence). The research budgets are completely financed by corporate funds, but the decentralised units and subsidiaries have to transfer a certain percentage of their revenues to the group. Beside the research budgets there are also local budgets for development activities of the single decentralised units. These development budgets are either financed by the decentralised units themselves or by customers (so-called order-related development).

### **E) Potential starting points for an internal R&D market**

Potential starting points for the direct interaction of supply and demand were particularly identified for line extensions. In this context the units that are close to markets and customers (e.g. centers of excellence or marketing companies) could initiate variants and make direct orders to the responsible R&D units. In return they should pay a price, which is negotiated between the supplying unit and the requesting unit. In this way an internal R&D market could possible lead to

- a consolidation of interests,
- a better estimation of development potentials,
- an improvement of the R&D-specific profitability,
- an improved communication between the involved parties, and
- a better integration of the R&D activities within other corporate functions.

## **BASF**

State: 2002

### **A) Key features of the company**

BASF is an international chemical group, which has a leading position in its five businesses (Chemicals, Plastics, Performance Products, Agricultural Products & Nutrition, and Oil & Gas). BASF's portfolio ranges from chemicals, plastics, performance products, agricultural products and fine chemicals to crude oil and natural gas. BASF maintains business relationships with customers in more than 170 countries and supplies approximately 8,000 products from its five segments to a wide range of industries worldwide.

In 2001 BASF had about 92,000 employees worldwide and achieved total revenues of 32.5 billion €, gross profits of 10.31 billion € and earnings before interest and tax of 1.22 billion €. Worldwide, approximately 8,000 employees work in R&D at BASF; thereof approximately 6,000 at the 'Verbund'-site in Ludwigshafen. Main research areas are specialty chemicals research, chemicals research and polymers research. In 2001 BASF invested 1.25 billion € in their R&D activities, which corresponds with a R&D quota of 3.84%.

## B) R&D projects

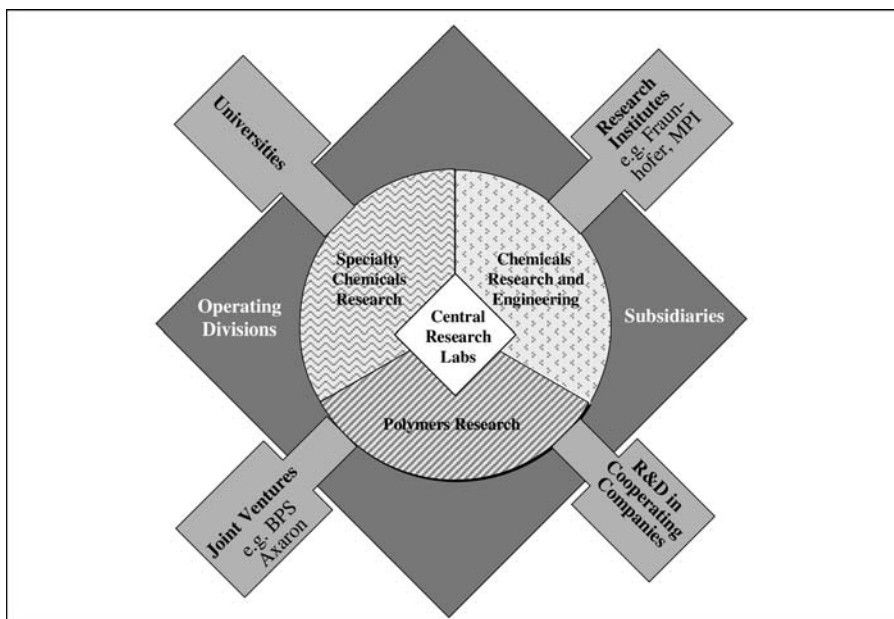
BASF distinguishes the following four types of R&D projects:

- Research & Technology projects
- New product development projects
- Projects for the development of new and improved processes
- Projects for the enhancement of existing products

Approximately 50% of the total R&D budget is used for the development of new products and further 20% are used for the enhancement of established products. In the development of new and improved processes BASF invests about 25% of the R&D budget, whereas approximately 5% are used for the exploration of new methods and technologies.

## C) R&D organisation

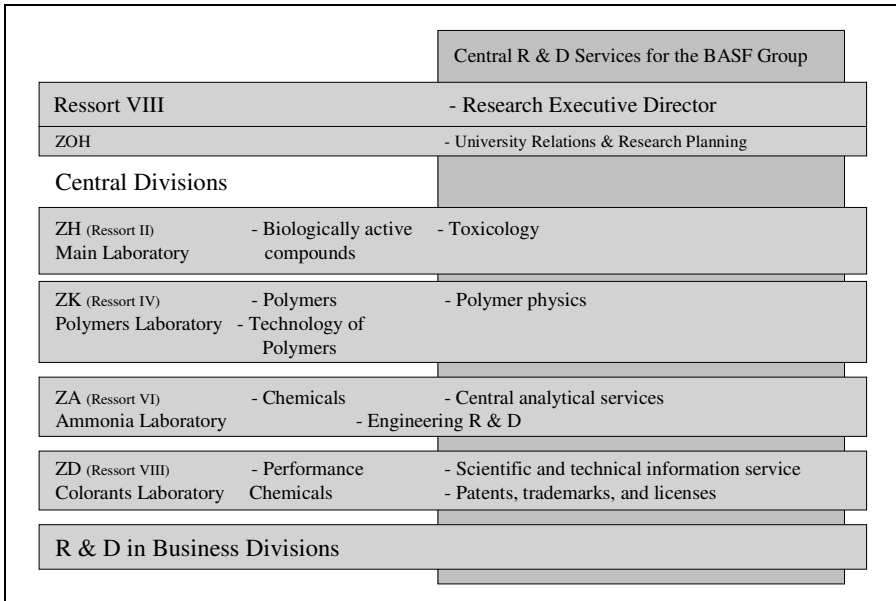
Successful research combines market stimuli with scientific discoveries to create innovative products. The organisation of research at BASF forms an integrated whole (Verbund in German) which is completely focused on this task (see Figure 55).



**Figure 55: Research-‘Verbund’ at BASF**

The central, corporate research laboratories at Ludwigshafen are the competence centers for active ingredients, materials of construction, special effect sub-

stances, chemicals, and process development. Decentralised development units in operating divisions and group companies are near to customer needs. Figure 56 illustrates how the R&D activities are organised at BASF:



**Figure 56: R&D organisation at BASF**

The responsibilities for the research activities are broadly distributed among the members of the BASF management board. One board member functions as the spokesman of research. This member has the task to cross-divisionally coordinate central aspects of the research. On the other hand the development activities are in the responsibility of the operating divisions and their business units. They conduct development activities in close cooperation with partners and customers world-wide.

About 45% of the R&D costs arise in the central research, whereas the remaining 55% arise in the decentralised operating divisions and their business units. The latter part of the costs again can be equally divided into R&D activities that are conducted by BASF’s internal R&D units and into R&D activities that are conducted by R&D units of BASF subsidiaries. The central research labs are organised as cost centers, whereas the operating divisions and business units are organised as profit centers and thus are responsible for their own profits. Likewise, they are responsible for the production and marketing of their products. Direct assignments of the operating divisions and/or business units to central research labs determine approximately 80% of the research budget. However, the exploratory research, which is also conducted by the central research labs, is financed completely by corporate funds.

#### **D) R&D resource allocation**

At least once a year the global steering committee of BASF, which consists of the representatives of the research units, the heads of the operating divisions as well as the heads of the product areas, come together to coordinate strategic and operative goals. This meeting is called 'R&D Strategy Talk'. The talks are concerned, for example, with the question which implications the respective strategy has on BASF's R&D concerning personnel, equipment etc. The single product areas reassess their strategies (goals concerning market shares or margins etc.) at least every three years in order to consider potential market changes as fast as possible. The R&D strategy talks are conducted in accordance with concrete guidelines, which predetermine the structure of the discussion. The talks aim at reaching an agreement between R&D and marketing with regard to the goals concerning the time needed for the creation of certain marketable project results. On top of this, opportunities, problems and conditions should be discussed. A further important member of the steering committee is an overall coordinator, which is responsible for the link between the central research (supplier) and the operating divisions (requestors). This coordinator has to ensure the smooth interaction between the parties that are involved in the resource allocation process.

After the strategic and operative guidelines have been determined a cross-divisional competition concerning the best project ideas starts. At the end of this competition the best ideas are developed into project proposals. The best proposals of each operative unit are selected by the responsible steering committees. This process takes place bottom-up and results in the research plan of the respective divisions. In a further step, all the divisional research plans are aggregated to the total research plan of BASF, which then has to be approved by the management board. Based on this total research plan a more detailed plan is derived, which comprises the required resources of all the involved units for the current year as well as for the following three years of the planning period. However, the decision concerning the actual use of the allocated resources has to be made by the heads of the respective operating divisions that are consequently organised as profit centers.

The main instrument for the objective evaluation of R&D projects is the net present value method. In order to forecast the expected revenues in an understandable way the market is taken as a starting point (number of potential customers, quantity, price etc.). This procedure requires a tight cooperation between R&D and marketing. Based on the development plan they derive the required time, milestones, resources, and activities. Moreover, they derive revenue expectations based on the corresponding marketing plan. In this way it can be achieved that qualitative factors (e.g. product target profile, market attractiveness, competitive situation) are linked with quantitative factors (e.g. market potential, market shares, price expectations etc.), so that a revenue and cost plan and thus a free cash flow plan can be established. At the same time a discussion and a critical analysis of the project is conducted by the parties that are involved in the development process (R&D, production, marketing etc.). In this context the interdisciplinary evaluation

of all relevant facts and figures has main emphasis in order to achieve a common understanding.

Beside the isolated project evaluation, the portfolio management is mainly concerned with the right mix of R&D projects. The arrangement of the portfolio is mainly based on the following criteria:

- strategic fit,
- value contribution of the single projects to the company's value,
- utilisation of synergies between projects, and
- risk diversification (particularly concerning the technological feasibility and the amortisation duration with regard to the R&D expenditures).

One tool which has proven useful in this context is a graph with axes for 'expected financial result' and 'probability of success,' in which the R&D costs that are possibly needed for finalising a project are indicated by the size of the circles, which represent the various projects. Such a portfolio analysis can be used to determine priorities and to control the allocation of resources if there are bottlenecks.

### **E) Potential starting points for an internal R&D market**

The resource allocation at BASF already shows some market-like elements. So, the predominant part of BASF's research budget (80%-85%) is already determined by direct assignments of the operating divisions and/or business units to central research units. In case a project was financed by one operating division and a further division benefits from the project results, it can (in exceptional circumstances) occur that the benefiting division has a share in costs. Normally transfer prices – that are often oriented on external market prices – are settled for inter-company transactions.

A market-driven resource allocation also seems to be possible at the crossing point between the exploratory research and the divisional R&D. The exploratory research is responsible for the cross-divisional R&D. Thus, the exploratory research is mainly concerned with research projects that are important for the whole group, particularly for the protection of the methodological competencies. Exemplary are the research activities in the nanotechnology area. In general, the exploratory research aims at initiating research projects that fit to the several product lines of the divisions and to the overall BASF portfolio. The main criterion for the evaluation of the favourability of an exploratory research project is the number of potential users. In this way the exploratory research wants to create the option to subsequently acquire add-on orders, which are financed by the requesting divisions. The exploratory research is mainly conducted in the central research unit and the corresponding initial budget is completely financed by corporate funds and strictly limited. In case that the available funds are not sufficient for important exploratory research projects, potential requestors could take over the financing of

such projects within the scope of an internal R&D market. In this way additional financing and crucial know-how could be secured. The complete resource allocation process concerning exploratory research projects was already illustrated in section 4.4.

Since BASF in future wants to open up new businesses faster and more efficiently it founded the BASF Future Business subsidiary in 2001. This venture company focus on fields that are outside of the existing businesses, but in which BASF has some know-how. These new businesses promise above average growth rates and should secure the future profitability of the group. Within the scope of an internal R&D market the single divisions and/or business units could directly request (and finance) certain research services from this BASF subsidiary. Due to the strong research character it can also occur that already started projects are terminated before they are successfully finished, since the project result would not fit into the overall portfolio. In such cases the provisional research results could be licensed or sold via an external R&D market.

## **BMW**

State: 2002

### **A) Key features of the company**

The BMW Group is a manufacturer of automobiles and motorcycles worldwide that concentrates entirely on premium standards and outstanding quality for all its brands and across all relevant segments. Along with its automotive concerns, the BMW Group's activities comprise the development, production and marketing of motorcycles, as well as comprehensive financial services for private and business customers. In the financial year 2001 the BMW group made revenues of more than 38.46 billion €. In total the BMW group employs approximately 97,000 co-workers. At its Munich headquarter the company has a central research and innovation center, in which almost 8,000 R&D specialists in all areas and disciplines use the most advanced methods and technologies in order to systematically convert new concepts and ideas into innovations. In total more than 5% of the revenues are spent for R&D activities.

### **B) R&D projects**

Since mid-2000 the company has grouped vehicle projects similar to one another in technical terms within so-called product lines under the same responsibility. Each product line covers 1-2 vehicle segments; MINI and its variants, for example, are developed in one product line. Operations within the product lines are closely linked to one another in order to capitalise on joint resources and develop product features in one and the same process. This saves both time and money and allows the rapid introduction of new technologies on a broad scale.

All in all the following three types of R&D projects are distinguished within the BMW group:

- Research and preliminary development projects
- Serial development projects
- Variants

While the research units predominantly deal with the implementation of research and preliminary development projects, the development units are concerned with the so-called serial development projects and variants.

### **C) R&D organisation**

The research and preliminary development is centralised in the research and innovation center in Munich, whereas the serial development projects and the variants are implemented mainly in the decentralised manufacturing plants. The innovation process of BMW can be subdivided into a preliminary phase and a standard development phase. In general, the whole process is based on the BMW vision and on certain demands that must be fulfilled, such as customer requirements, safety, fuel consumption, emissions, recycling of raw materials, legal requirements etc.

On this basis ideas for potential innovations are generated and targets are defined. After the ideas have been successfully developed into project proposals a so-called council (steering committee) assesses the different alternatives and selects the most promising ones. Thereafter, the standard development phase can start. The respective projects are implemented in project teams. During the development process, three questions are of primary importance for the BMW Group:

How fast can a vehicle be developed? How fast can it be produced? How fast can we get it to the customer? The answer to the last two questions lies in the production process. And to optimise vehicle development, the BMW Group has created the product creation process, known as PEP.

PEP distinguishes between early development phases and series development. The early phase includes working out overall vehicle and production concepts and evaluating them economically as well as pre-developing components and technologies. The goal of the series development which follows is rapid realisation of the vehicle concept. During the whole process as many individual tasks as possible are handled simultaneously (simultaneous engineering). All participants in this process, including suppliers, are in constant contact with one another. Innovative technical and computer-supported methods support this process. Today, not one series vehicle developed by the BMW Group hasn't been imaged, tested and optimised virtually – before becoming a reality. At the end of the innovation process the finished product has to be launched in the international markets.

#### **D) R&D resource allocation**

In general, BMW has different kind of R&D budgets. On the one hand there is a budget for the research and preliminary development activities. On the other hand there is a budget for serial developments and variants. The research and preliminary development budget is financed by the group and is not bound on specific product lines. The total budget can be subdivided into a fixed basic budget that is assigned to the respective development units and a centrally steered zero based budget for the actual research and preliminary development projects. The serial development projects and the variants are financed by the development budgets of the divisions. In addition to the regular budget there exists also an innovation fund for the short-term financing of projects during the year. As soon as a model unbound research project can be assigned to a certain target vehicle, the further development is financed by the corresponding development budget of the respective division.

The central decision-committees in this process are the so-called councils. The councils consist of multidisciplinary experts that have to steer the realisation of innovations in the early stages. In the end the main decision competence concerning the prioritisation of projects within the scope of the yearly budgeting process has the so-called advanced development committee. The main decision dimensions for the selection of research projects are profitability, technology, and time. The selection of serial development projects and variants is based on the dimensions profitability, weight, reliability, flexibility, and time.

The actual budgeting process, however, starts with the generation of ideas in certain potential areas. Thereby BMW is not only interested in the ideas of its own R&D departments, but also in the creative minds outside the BMW Group. Thus, BMW seeks contact with small and medium-sized innovative companies. These potential partners can submit their ideas through the Virtual Innovation Agency (VIA). The overall evaluation and selection of the resulting ideas is then made by the responsible councils and the advanced development committee. The final innovation programme is eventually approved by the management board and the head of development.

#### **E) Potential starting points for an internal R&D market**

The premium supplier in the automobile sector have the problem that the breakthrough-innovations are usually firstly used by the ‘flagships’ of their product lines. This, however, bears the consequence that the development costs present a heavy financial strain on the top products. Currently, for example, the iDrive is firstly applied in the BMW 7 series, which in consequence has to bear approximately 90% of the total development costs of the iDrive-technology. In case that this technology is applied in the previous series as well, a so-called innovation lump sum is charged. However, the settled amount often only covers a small share of the former development costs, since it is not oriented on economical calculations but rather on the financial possibilities of the respective series. In this context

a market-driven allocation could possibly lead to a more precise settlement of the development costs of a technology.

As stated before, BMW has created a so-called innovation fund for the financing of promising projects during the year. Based on the innovation areas certain target criteria for single systems and components are derived. Thus, for example, the target criteria for a certain engine component are required space, weight, or contribution to emissions reduction. In this context it would be conceivable that the actual data concerning the required space are lower than intended, whereas the actual weight is higher than intended. This different fulfilment of the formerly set up targets could be possibly compensated via the implementation of market mechanisms. This means that the buffer concerning the required space could be exchanged for a weight reduction, e.g. through the usage of another kind of material. In this way the involved parties could possibly balance the target criteria that fell short and the criteria that are exceeded via an internal R&D market.

## **DaimlerChrysler**

State: 2002

### **A) Key features of the company**

The product portfolio of DaimlerChrysler ranges from small cars to sports cars and luxury sedans; and from versatile vans to heavy duty trucks or coaches. DaimlerChryslers' passenger car brands include Maybach, Mercedes-Benz, Chrysler, Jeep, Dodge and smart. Commercial vehicle brands include Mercedes-Benz, Freightliner, Sterling, Western Star and Setra. It offers financial and other automotive services through DaimlerChrysler Services. DaimlerChrysler's strategy rests on four pillars: global presence, strong brands, broad product range, and technology leadership.

DaimlerChrysler has a global workforce and a global shareholder base. With 372,500 employees, DaimlerChrysler achieved revenues of EUR 152.9 billion € in 2001. Around 28,000 employees are working worldwide on the R&D of technical innovations. In total DaimlerChrysler spent 6 billion € for their R&D activities in 2001, which is equivalent with a R&D quota of approximately 4%.

### **B) R&D projects**

At DaimlerChrysler the following three main types of R&D projects can be distinguished:

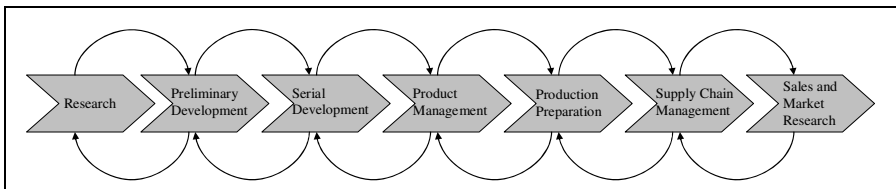
- Research and preliminary development projects
- Development projects
- Contract development projects (Variants)

In addition to the above typology the R&D projects are also categorised according to their financing. The so-called A-projects are completely financed by corporate funds. The so-called B-projects are financed by the divisions and/or business units. And the so-called C-projects are financed by externals (e.g. customers).

### C) R&D organisation

DaimlerChrysler has a central research unit that is located in Stuttgart. The development activities are however mainly decentralised and are conducted in the divisions and/or business units. Worldwide DaimlerChrysler has approximately 28,000 R&D specialists. DaimlerChrysler registers around 2,000 patents every year, thus securing its technology and innovation leadership and an important long-term advantage in the face of an increasingly tough global competition. The research unit at DaimlerChrysler consists of three research areas, which are in charge of the respective research managers. The superior research director is member of the DaimlerChrysler management board and responsible for the R&T activities.

The innovation process at DaimlerChrysler normally consists of the following stages presented in Figure 57.



**Figure 57: Stages of the innovation process at DaimlerChrysler**

The organisation of the innovation process is oriented on the following guiding principles:

- a) We delight our customers for the ‘star’ (pull strategy instead of push strategy)
- b) We have an open management culture (bottom up instead of top down)

Outside the company this means a high customer orientation and inside the company this means a high employee orientation. In this context the dismantling of department borders on a horizontal and a vertical score, through the stimulation of a less bureaucratic and problem solution oriented teamwork, plays an immense role. Out of this result the following further guiding principle:

- c) We want to be the best in innovation, quality and profitability

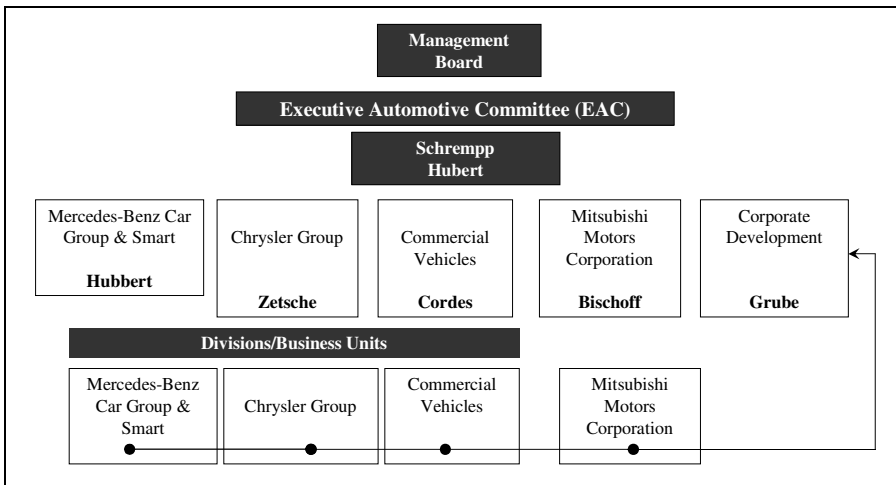
Moreover, from an organisational perspective a forum was established, which consists of interdisciplinary experts. This forum should promote creativity and the exchange of views and thus should contribute to the generation of innovative product ideas. Members of this forum are experts from the following areas: Research, preliminary development, serial development, product management, pro-

duction preparation, supply chain management, sales and market research. Thus, the expert forum rises to the position of an inherent element of the innovation process. Further important element of the innovation process is the inclusion of partners as well as the sustainability concerning the environment.

**D) R&D resource allocation**

The decisions within the scope of the innovation process take place bottom up, but the lower management levels are responsible for the pre-selection of ideas and project proposals. The remaining project proposals are then forwarded to the competent steering committee, which prioritise the proposals.

Figure 58 exemplarily shows the composition of the Executive Automotive Committee (EAC).



**Figure 58: Executive Automotive Committee at DaimlerChrysler**

The final research plan is eventually approved by the management board in coordination with the relevant heads of the research unit and the divisions. The course of the complete research planning process and the fundamentals of the resource allocation were already discussed in detail in section 4.4.

As soon as a research project, respectively, a preliminary development project has achieved a high degree of ripeness and the feasibility of the project is largely ensured, the relevant department forwards the project to the competent steering committee and recommends that the project should be transferred into a development project. In this context DaimlerChrysler has an ambitious goal, since they want to establish the world best product development management in combination with the world best output. From this the following sub goals can be derived:

## a) Product goals

- Highest standard in safety, quality, and innovation

## b) Process goals

- Efficiency improvement (through a shortening of the development times)
- Push innovations (at least 10 genuine innovations compared with the previous production series, at least 6 months before the competition)
- Quality improvements (through a consequent orientation on customer requirements)

## c) Total Quality Management goals

- Ability to recognise and perform necessary changes
- Comprehensive and process-oriented way of thinking and discipline concerning the compliance with agreements, goals, dates, budgets, and costs

Beside the financial forecasts and calculations concerning the project values (NPV etc.), the criterion ‘strategic fit’ as well as the know-how of experts (‘gut feeling’) are the main decision criteria within the scope of the portfolio management; particularly for research projects. In addition to that feasibility studies concerning the single projects are conducted, which can have a decisive influence on the actual allocation of resources.

### **E) Potential starting points for an internal R&D market**

Within the resource allocation processes at DaimlerChrysler some market-like elements can be identified: Beside the ‘market place’ for ideas in the Intranet there are further starting points for market-driven forms of resource allocation. The allocation of resources takes place in form of an acquisition process and the budget that is financed by the divisions is determined within the scope of negotiation processes. Here the divisions in advance pay money into a central research fund. Later the actually requested R&D services are offset against the previously paid money.

In principle, the divisions try to avoid paying too much money in advance. Thus, the division’s financing of research activities and with it the use of previous capacities is getting more uncertain. Through this organisational arrangement the number of direct assignments from the divisions has been considerably increased in recent years. This is particularly due to the fact that the divisions don’t have to make binding agreements in advance.

## **Henkel**

State: 2002

### **A) Key features of the company**

The Henkel Group operates in three strategic areas of competence - Home Care, Personal Care, and Adhesives, Sealants and Surface Treatment. These strategic business areas are organised into four globally operating business sectors within the Henkel Group: (1) Laundry & Home Care, (2) Cosmetics/Toiletries, (3) Consumer & Craftsmen Adhesives, and (4) Henkel Technologies. The Henkel Group is headquartered in Düsseldorf. It has a total of around 50,000 employees with 77 percent working outside Germany. In total the company achieved 9.41 billion € with its ongoing businesses. Securing the future through innovation is the core task underlying Henkel's R&D effort. Innovations are crucial to Henkel's competitiveness and thus its continued success. The average number of employees engaged in research, product development and application engineering at Henkel worldwide was around 3,000 in 2001. Expenditure on R&D at the Henkel Group amounted to 255 million €. This corresponds to a R&D ratio in relation to sales of 2.7%. Of the total amount, 35 million € went into Central Research and 220 million € into the product and process development activities of the business sectors.

### **B) R&D projects**

The following general R&D project types can be categorised at Henkel:

- Research projects (so-called basic development projects)
- Product development projects
- Technical services projects

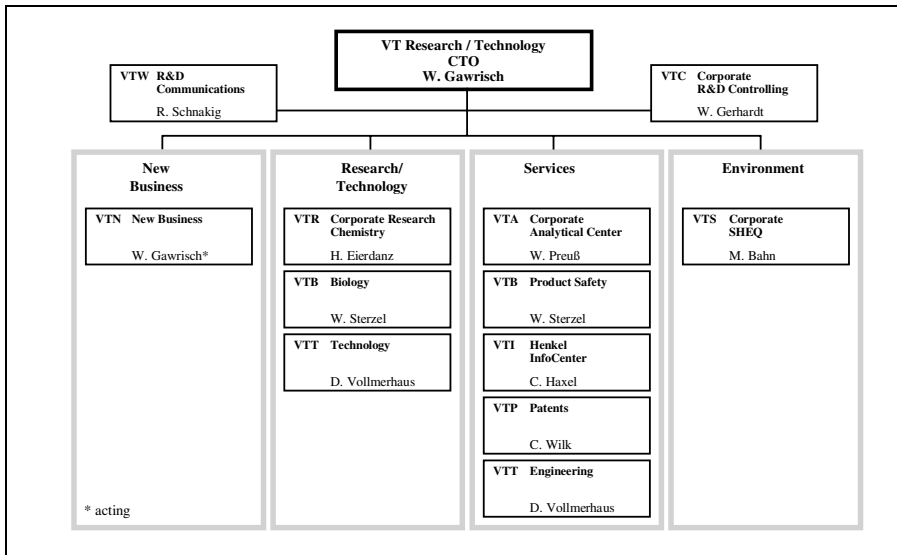
Real preliminary development projects do not exist at Henkel. However, before a project is started so-called feasibility studies are conducted, which have the character of preliminary development projects. This is due to the fact that Henkel only wants to start a project if one may have a certain picture concerning the overall targets and the feasibility of a project. A further speciality is the so-called technical services projects that are conducted in order to enhance or further develop products, which have already been introduced into the markets.

### **C) R&D organisation**

The research activities at Henkel are organised centrally and are steered by the R&T unit, which is organised as a cost center. The budgeting process takes place top down. The research activities are completely financed by corporate funds with the exception of technical services projects. The services (e.g. analytics or patents)

are offered via a catalogue and the requesting divisions and/or business units have to pay the corresponding transfer prices.

The organisation of Henkel’s R&T activities is illustrated in Figure 59.

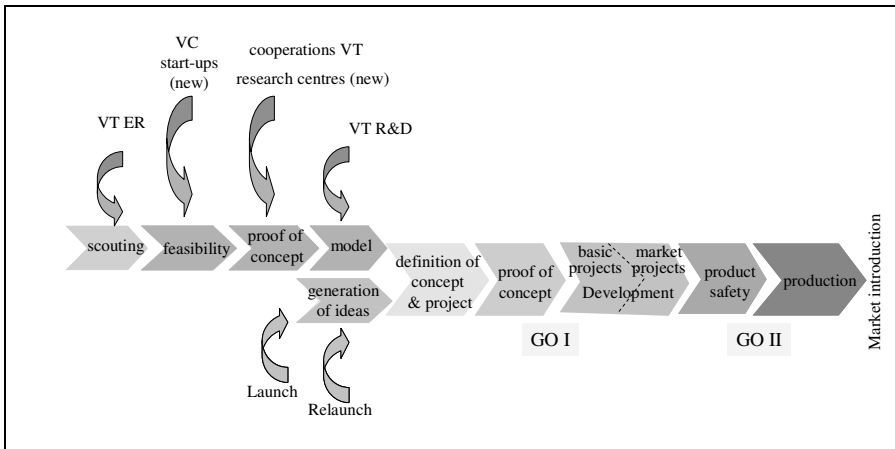


**Figure 59: R&T organisation at Henkel**

Moreover, there are also a multitude of research laboratories that are internationally dispersed. However, these labs are centrally steered and coordinated by the R&D management of the respective division. Each division has its own product development unit, which is structured according to the required competencies of the respective unit. Thus, the product development projects are conducted in the decentralised units that also ensure the necessary funding.

The geographical organisation of the R&D activities depends on the markets. So, for example, the division laundry & home care as well as the cosmetics division are predominantly active in Europe and have dispersed R&D infrastructure in this region (according to the requirements of markets).

The subsequently shown ideal typical innovation process (see Figure 60) can be subdivided into two main phases. It has to be distinguished between research activities on the one hand and development activities on the other hand. The research activities cover the so-called scouting and the feasibility studies. These stages are mainly concerned with the determination of new research fields and with the gathering and processing of the relevant data for the definition of concrete projects. Moreover, a first model design (proof of concept) must be developed. This conceptualised model design serves straightaway as a basis for the definition of a development project, which aims at a new or improved products. In total product innovations make up about 90% of the research activities.



**Figure 60: Innovation process at Henkel**

The innovation process at Henkel is clearly structured. In a first step, it is important to generate a multitude of promising ideas without consideration of evaluation criteria. These ideas are potential starting points for the respective divisions in order to develop new project proposals.

Subsequently, each division conducts an internal scouting, which results in concrete project proposals that are subsequently further developed into concrete project applications. The most lucrative projects are then selected by the Steering Committee R&T. Thereafter, the implementation of the selected projects can start. The project controlling and steering follows strategic, technological and economical factors.

#### **D) R&D resource allocation**

The resource planning concerning the R&D budget takes place once a year. The process starts usually in the middle of the year and takes place initially bottom up. The competent steering committees (SC) of the relevant areas (SC New Businesses, SC Services, and SC R&T) decide all year round in a revolving system upon the single project applications and select the most promising ones. The corresponding resource plan then has to be approved by the management board in November. Thus, in the end the management board has the decision power concerning the R&D budget of the following business year.

Henkel's product development is clearly driven by the markets and is carried out in the decentralised divisions by the competent project teams. The planning of the central research programme takes place in a revolving way. This means that all projects are individually reviewed on certain predetermined dates in order to prove the fulfilment of certain milestones. The control of the progress of projects is in the responsibility of the SC R&T, which again has to immediately report to the management board. The central research and the divisions together defined 8

research platforms. On the basis of these platforms the research projects are executed in the central research unit. However, there is a periodical coordination with the respective divisions. The research projects are completely financed by corporate funds, since the research activities are centrally organised and have in tendency a stronger long-term horizon than the development projects, which are financed by the respective divisions. Furthermore, the research activities should aim at strategic initiatives that prepare Henkel for the future.

### **E) Potential starting points for an internal R&D market**

As already discussed in section 4.4, Henkel has already applied a market-like allocation for their technical services projects. The ‘Services’-function is assigned to Henkel’s R&T division and comprises the following units: (1) Corporate Analytical Center, (2) Product Safety, (3) Henkel Information Center, (4) Patents and (5) Engineering. These units offer their services via an intranet-based service-catalogue to the requesting divisions and business units. In return the requesting units have to pay a price to the supplying service units. The settlement takes place in form of transfer prices. In this context it must be pointed out that these transfer prices are cost-oriented prices and are not the result of negotiations between suppliers and requestors. The competition in this market-like arrangement can be described as rather strong, since there are a lot of external suppliers that offer the same services. If these external suppliers offer the same quality of service at lower cost the internal requestors are allowed to purchase the needed services externally rather than from the more expensive internal service unit. By applying this form of market-like resource allocation Henkel considerably increased the performance and the service quality of its internal service units.

Another kind of internal R&D market appears to be suitable for the exchange processes between the central research (with its 8 research platforms) and the divisions. On the basis of the research platforms technology-driven projects are implemented. At a certain point (e.g. proof of concept) the project results are then transferred to the respective divisions. However, the form of financing prevents an internal market solution, since the project costs are completely financed by corporate funds. An internal R&D market, however, would require that the requestors (divisions) have to pay a price for the offered research results.

The utilisation of external know-how to supplement Henkel’s own core competencies is becoming increasingly important. Henkel, thus, intends to invest more heavily in venture capital funds and start-up companies, and to enter into research partnerships worldwide. In this context an internal R&D market could possibly intensify the interaction between the involved parties and could, moreover, improve the communication and the exchange of knowledge. This on the other hand should shorten the underlying resource allocation processes and reduce the time-to-market of new products.

## **Hilti**

State: 2002

### **A) Key features of the company**

The Hilti Group is a world leader in developing, manufacturing and marketing added-value, top-quality products for professional customers in the construction industry and in building maintenance. Hilti's product range covers drilling and demolition, direct fastening, diamond and anchoring systems, firestop and foam systems, installation, measuring and screw fastening systems as well as cutting and sanding systems. Hilti operates in over 120 countries around the world. The workforce of Hilti comprises more than 14,000 employees, of which two-thirds work directly for customers, in sales organisations, engineering and customer service. Hilti has production plants and R&D centers in Europe, America and Asia. The corporate headquarter is located at Schaan in the Principality of Liechtenstein. In the financial year 2001 the company achieved total revenues of 3.12 billion CHF. The R&D expenditures amounted to 135 million CHF, which was equivalent with a R&D ratio of approximately 4.5% in relation to total revenues.

### **B) R&D projects**

At Hilti the following three general types of R&D projects are distinguished:

- Research & Technology projects
- Product development projects
- Product enhancement projects

The R&T projects are carried out centrally by the unit 'New Business & Technology'. However, product development projects are conducted decentrally in the business units. With regard to the product enhancement projects, it must be remarked that they are often an integral part of the product development projects.

### **C) R&D organisation**

Hilti's corporate research is centralised at Schaan in the Principality of Liechtenstein. Furthermore, Hilti has several development centers around the world (e.g. Germany, China). The research activities focus on elementary processes of the construction industry and building maintenance. The main research disciplines are physic and simulation, construction technology, raw materials etc. From an organisational point of view the research activities take place in the centralised unit 'New Business & Technology,' which consist of 9 competence centers in total. The integration of the R&D activities into the other functions of the Hilti group takes place via interdisciplinary project teams. On the strategic level the

integration in the innovation process takes place via the strategic innovation planning, which is conducted during the yearly corporate innovation workshop by interdisciplinary working teams. On the operative level the integration in the innovation process takes place within the scope of the product development projects. Subsequently, the business units are responsible for the development and the distribution of products.

In practice the product development takes place in tight cooperation with the corresponding market organisations. In case of the introduction of a newly developed tool the product management puts together the training material; to this theory the individual countries add practical training, so that the sales teams can thoroughly serve and professionally advise their customers. The individual country marketing organisations adapt for their different sales channels and specific target groups the marketing tools that the product management at Hilti headquarters has developed together with communications specialists.

#### **D) R&D resource allocation**

In the central research unit ‘New Business & Technology’ there are two main research programmes that are characterised by different responsibilities. On the one hand there is a research programme which is financed centrally by corporate funds. Approximately 40% of the total ‘New Business & Technology’-budget is available to this programme. In this context the reporting concerning this research programme takes place directly to the executive board of Hilti. On the other hand there is a second research programme for which the remaining 60% of the total ‘New Business & Technology’-budget are used. The second research programme is partly financed by corporate funds. However, around 50% of the budget for this research programme has to be determined by direct assignments of the decentralised business units to the central research unit. The reporting concerning this programme takes place directly to the corresponding business areas and its business units.

The basis for the determination of the business unit budgets are the respective budgets of the previous year (continuation of budgets). However, adjustments are made according to the strategy check and the project prioritisation. In total 135 million CHF are available for the implementation of R&D projects. This total budget is allocated in the following way: All business units, respectively, business areas as well as the central research unit ‘New Business & Technology’ prioritise their projects. Then, for example, approximately 80% of the required funds for the prioritised projects are financed by the budgets of the decentralised business units. The remaining projects are then united in a central portfolio, which serves as the basis for the allocation of the remaining 20% of the business unit budgets. In recent years approximately 15%-20% of the total R&D budget was allocated on R&T projects, whereas 80%-85% of the total R&D budget was invested for new product development and enhancement projects.

Within the above-illustrated allocation process the following decision and/or evaluation criteria are applied: Possibility to patent a technology, differentiation potential compared with competitors, market attractiveness, and economical relevance for customers.

### **E) Potential starting points for an internal R&D market**

Hilti already applies the market instrument of direct assignments. Moreover, the corporate innovation workshop, which is conducted yearly, can be described as a market place, on which the involved actors mutually exchange ideas and generate new ones. In addition to that the establishment of an electronically platform (e.g. Intranet as a market place) could lead to an improved communication and a better recognition and utilisation of synergies. However, it must be considered that a huge part of the information exchanges in the R&D field takes place via informal relationships.

## **Roche**

State: 2002

### **A) Key features of the company**

Roche is a leading healthcare company with a broad spectrum of innovative solutions. For more than 100 years, Roche has been active in the discovery, development, manufacture and marketing of novel healthcare solutions. Its products and services address prevention, diagnosis and treatment of diseases, thus enhancing well-being and quality of life. Arranged in two operative divisions, Roche's global mission today and tomorrow is to create exceptional added value in healthcare. These two units are: (1) Pharmaceuticals, and (2) Diagnostics. Roche is number one in the global diagnostics market and is the leading supplier of pharmaceuticals for cancer and a leader in virology and transplantation. In 2001 Roche employed roughly 63,000 people in 150 countries. In total the group achieved revenues of 29.16 billion CHF in 2001, of which it spent 3.89 billion CHF in its R&D activities. This is equivalent with a R&D ratio of more than 13% in relation to total revenues. The Group has alliances and R&D agreements with numerous partners.

The Roche case study was conducted in the diagnostics division. About 2,000 scientists around the world are committed to developing new diagnostic tools and services for diagnostic laboratories as well as for patient self monitoring. In addition, Roche Applied Science is dedicated to provide the science community with best research tools. In 2001 Roche Diagnostics invested 627 million CHF (around 10% of the divisional turnover of 6.3 billion CHF) in R&D. All Business Units – Roche Molecular Biochemicals, Roche Molecular Systems, Roche Laboratory Systems, Roche Patient Care – are at the forefront of technological innovation in

their respective field, with R&D focused on: Instrumentation and reagents for the research and science communities, clinical chemistry, immunochemistry, coagulation, haematology, laboratory automation, diabetes monitoring, and point of care.

### **B) R&D projects**

At Roche Diagnostics the following three general types of R&D projects can be categorised:

- Research & Technology projects
- New product development projects
- Product enhancement projects

### **C) R&D organisation**

Within the Roche group there does not exist a cross-divisional central research unit. Rather each business unit of the respective divisions has its own R&D unit. So-called ‘Centers of Excellence’ combine R&D, manufacturing and global marketing support activities in one site in order to bring together higher quality products to the market faster and at lower costs. All the research projects of the business unit ‘Centralised Diagnostics’ are, for example, conducted at the center of excellence at Penzberg (Germany). New development and enhancement projects are, however, carried out in the respective country organisations at internationally dispersed locations. The corresponding R&D budgets of the business units are predominantly financed by the business units themselves. The integration of the R&D activities within the other functions takes place via so-called ‘Global Product Portfolio Teams,’ which consist of interdisciplinary experts. The sales specialists from the country organisations (marketing companies) are also members of these teams.

In the business unit ‘Centralised Diagnostics’ R&D projects are organised in a matrix structure, which consists of treatment areas (Serum Work Area, Coagulation, etc.) on the one hand and research fields on the other hand (Clinical Chemistry, Immunology, etc.). The Centralised Diagnostics Growth Team in cooperation with the Centralised Diagnostics Market Management coordinate R&D projects that aim at new businesses and markets with R&D projects that aim at existing businesses and markets. In this way it is ensured that the conducted R&D activities are in line with the overall strategy of the respective division. Beside the coordination of new and existing businesses, the above-mentioned committees are particularly responsible for the coordination between R&D on the one hand and Marketing & Sales on the other hand. A further important issue concerning the R&D organisation at Roche is the longstanding and ongoing tradition of working with outside scientists.

#### **D) R&D resource allocation**

The global R&D budget of Roche Diagnostics is allocated top down to the respective business units. Around 50% of the budget is used for new and further developments, whereas 37.5% are used for the harmonisation of systems. The remaining 12.5% are spent on the cultivation of development partnerships. Roche has forged alliances with some of the most forward-looking and technologically advanced companies in the world. In addition, Roche scientists maintain a vast network of collaborative and consultative relationships with leading academic researchers around the world in many different scientific fields. Depending on the estimates and the underlying planning horizons, the Global Product Portfolio Teams and the Market Management Teams allocate the corresponding resources to the respective product lines. According to this basic resource allocation the Product Line Teams (PLTs) allocate the resources to the respective R&D projects. The actual use of the resources is then supervised by the competent Programme Management Teams (PMTs).

Within the above-illustrated resource allocation processes the following decision criteria are applied: For R&T projects the evaluation of existing and new projects takes place mainly in form of portfolio techniques. As criteria serve, on the one hand, the ripeness of a business, which is normally measured via the attractiveness of a technology. On the other hand the potential revenues of a new business must be estimated (market attractiveness). For the evaluation of new development projects and enhancement projects the following basic evaluation dimensions are applied: (1) Time-to-market, (2) development costs, and (3) the qualitative characteristics of the strived specifications. The main quantitative project evaluation instruments are the net present value method (NPV) and the internal rate of return method (IRR). For huge and resource-intensive projects in exceptional cases additionally the option pricing method is applied.

#### **E) Potential starting points for an internal R&D market**

Market-driven forms of resource allocation are basically conceivable in areas where the so-called ‘consumerisation’ has strongly marched on, i.e. on markets with a strong customer orientation. In this context the units that are close to markets and customers (e.g. centers of excellence or marketing companies) could initiate variants and make direct orders to the responsible R&D units. In return they should pay a price, which is negotiated between the supplying unit and the requesting unit. However, it is assumed that financially strong requestors could exercise a too strong market power within the scope of internal R&D markets, which again could lead to a too short-term orientation of the project portfolio. Because of this reason strategically important projects should be excluded from internal market solutions in the R&D field and, moreover, these projects should be financed centrally by corporate funds.

## Syngenta

State: 2002

### A) Key features of the company

In 1999 Novartis and AstraZeneca announced spin-off followed by merger of agribusiness activities. This was the launch of Syngenta – the first global ‘pure play’ agribusiness company, operating in all major areas of crop protection and seeds. At present Syngenta has a global total of more than 20,000 employees. Based on 2001 combined sales of 6.32 billion US\$, the crop protection division of Syngenta would have been the world leader in fungicides, and number two in herbicides, insecticides and seed treatments. Their seeds division would have been number three in the world. Crop protection will contribute 5.38 billion US\$ and seeds 0.94 billion US\$. With a combined R&D investment of 700 million US\$ and a R&D staff of over 5,000 employees, Syngenta has a powerful capability to invent, develop and sustain innovative products.

Syngenta’s global offer is subdivided into seven Product Lines, five for Crop Protection (Selective Herbicides, Non-selective Herbicides, Fungicides, Insecticides, and Professional Products) and two for Seeds (Field Crops, and Vegetables & Flowers). Syngenta has major research and manufacturing facilities located in more than 20 countries around the world. Syngenta’s major research sites are located in the heart of scientific communities.

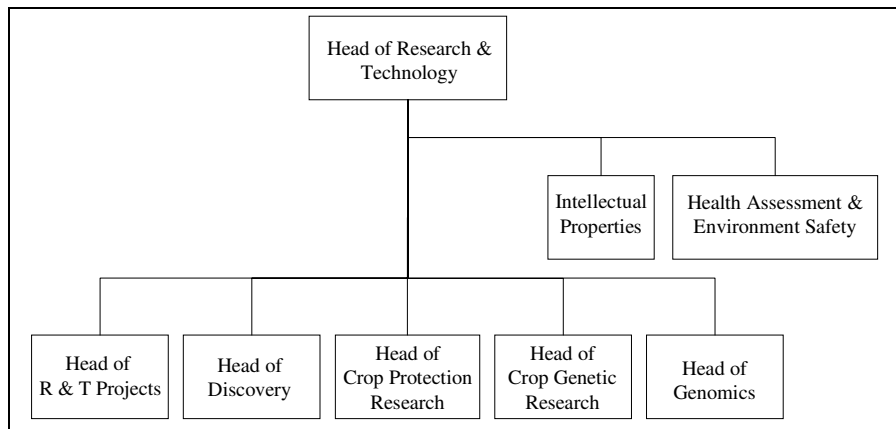
### B) R&D projects

Each project is measured against specific milestones and a generic project progression plan (stage plan) and it is part of a portfolio of related projects. The following general types of R&D projects can be distinguished at Syngenta:

- Research projects
- Product development projects
- Product enhancement projects

### C) R&D organisation

The R&D activities are predominantly conducted in the local scientific communities. Nevertheless, especially the research activities are centrally coordinated. Therefore, the following R&T organisation has been implemented (see Figure 61).



**Figure 61: R&T organisation at Syngenta**

Syngenta needs about ten years from first synthesising a compound to its penetration in major markets.

The corresponding innovation process is segmented into the following four stages:

- Stage 1: Research
- Stage 2: Evaluation
- Stage 3: Active Ingredient Development
- Stage 4: Life Cycle Management

In the Research stage the task is to search for active ingredients with performance characteristics complying with user needs, the business strategies and company policy and to determine early the potential issues for identified development candidates.

In the Evaluation stage the relevant characteristics of development candidates will be thoroughly evaluated to justify development and investments. The focus is on biological performance, safety profile, registration and technical feasibility, market opportunities and patent situation.

In the following Active Ingredient Development stage the development of the active ingredient to complete biological, regulatory, commercial, process and manufacturing activities in specific territories and markets is carried out.

The final stage is Life Cycle Management. In this stage it is important to develop the active ingredient and formulations in all important markets to achieve targeted sales within the shortest time and to achieve maximum contribution through optimum utilisation of design characteristics, marketing and cost-reduction opportunities. Also it is important to adapt products and uses to customers’ changing needs and to develop post-patent strategies. At the end of this stage the active ingredient is phased-out from Syngenta range.

Figure 62 illustrates the innovation process on the basis of the design of an active ingredient (AI).

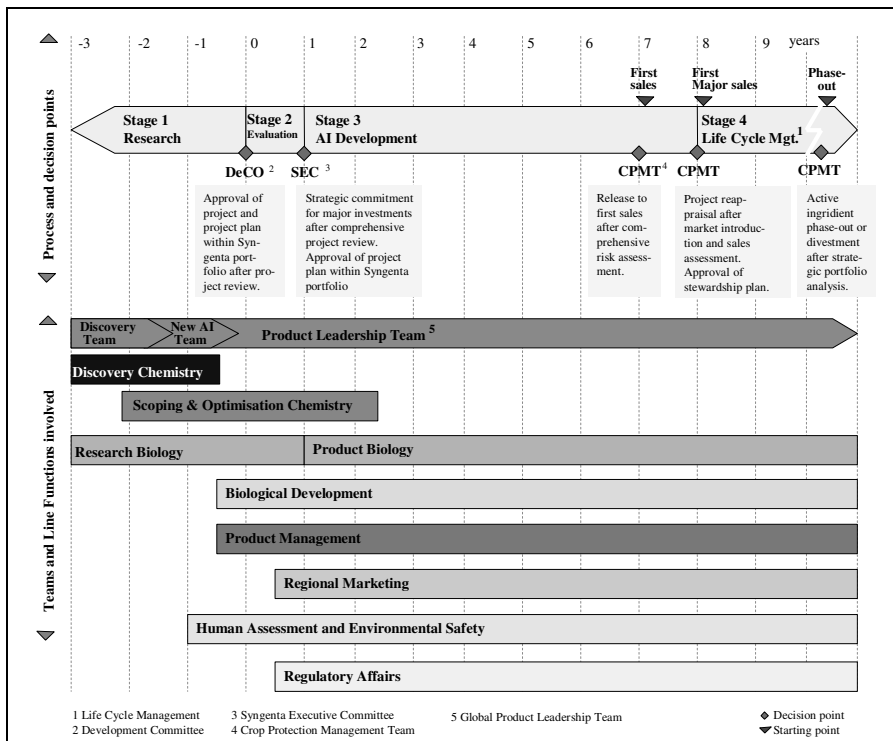


Figure 62: Innovation process at Syngenta

### D) R&D resource allocation

The organisation of the R&D resource allocation at Syngenta was already discussed in detail in section 4.4. Also the main decision flows as well as the most important decision criteria were described.

In addition to that Table 40 presents an overview of the most important teams and committees, which are involved in Syngenta’s innovation and product development processes. Moreover, the main tasks of these committees are explained.

Decision Committees	Tasks
Global Product Leadership Team (Global PLT)	Global Team of regional and line functional representatives with leading role in the development and life cycle management of active ingredients and corresponding products. Major tasks are to synchronise and optimise cost-efficient development of active ingredients and products oriented to user needs.
Regional Product Leadership Team (Regional PLT)	Regional Team of region and country representatives with a leading role in the development and life cycle management of AI, global and regional products. Major tasks are to synchronise and optimise cost-efficient development of products, which are successful in the markets. The Regional PLT drives the regional part of global projects in connection with the Global PLT.
Development Committee (DeCo)	Committee performing technical reviews on proposals from PLTs for AI stage promotions, for release to first sales of AIs / products, and making recommendations to the CP Management Team. DeCo regularly reviews projects (incl. formulation projects with high technical risks), assesses achievements, proposes or decides on corrective measures where necessary. Members are Headoffice line functional managers with a leading role in the development of AI and corresponding products. Representatives from Regions, Product Lines or specialists attend on a project basis.
CP Management Team (CPMT)*	Leadership team of the Crop Protection Division. CPMT is responsible for the active ingredient and product portfolio. It provides resources, infrastructure, and effective guidance and support for the Global PLTs. It monitors adherence to Syngenta standards and procedures to the extent necessary to achieve operational excellence, to manage risks and to enable operation as one coherent company.
Regional Management Committee (RMC)*	The Regional Management Committee is responsible for the definition of crop strategies and the implementation of these strategies through the execution of global and regional projects. It provides adequate resources, infrastructure, and effective guidance and support to the Regional PLTs. It monitors adherence to Syngenta standards and procedures to the extent necessary to achieve operational excellence, to manage risks and to enable operation as one coherent company.
Syngenta Executive Committee (SEC)*	Leadership team of Syngenta. Main forum that deals with all matters of worldwide interest. It reviews the divisional portfolio and allocates to the Global functions the resources for the development and maintenance of active ingredients and global products as well as regional projects.
*List of product development and portfolio management responsibilities only.	

**Table 40: Syngenta’s decision-committees and their tasks**

### **E) Potential starting points for an internal R&D market**

The case study illustrates that the current organisation of the R&D resource allocation at Syngenta is characterised by a multitude of hierarchical decision-committees. The instrument of direct assignments is only applied to a low extent. Thus, based on the actual state of the R&D resource allocation it must be examined if a stronger market-orientation of the R&D resource allocation processes can lead to effectiveness and/or efficiency improvements. The corresponding recommendation model for the systematic design of internal R&D markets is illustrated in section 7.2.

## Appendix 2 – Questionnaire

Case:

**“Efficient Resource Allocation in Research & Development  
– Market vs. Hierarchy”**

### THE PROJECT

With support from the **German Federal Ministry of Education and Research**, the **Competence Center for Innovation and Market-Oriented (Business) Leadership** at **Ludwigshafen University of Applied Sciences**, has developed a survey for international, technology-intensive companies, which aims at exploring if, and under what conditions an **internal market** for the **resource allocation** of **R&D processes** can be instituted.

### YOUR CONTRIBUTION

We have selected you as an international, technology-intensive company; and kindly ask you to complete this questionnaire. It has been shown that you would need between approximately **20 and 30 minutes**.

### YOUR BENEFIT

In return for your cooperation, you can receive upon request a **summary of the results** once the questionnaires have been evaluated. You will receive information regarding the following findings:

- current approaches to **R&D resource allocation**
  - important **trends** and successful approaches for the **allocation of scarce resources in R&D**
  - **design recommendations** for market-based allocation mechanisms for the financing of R&D projects
- 
- Yes, we would like to participate in this survey, and we are **interested** in the results
  - Yes, we would like to participate in this survey, but we are **not interested** in the results

## GLOSSARY

In this questionnaire, we examine the following three R&D project types:

1. **Research & Technology projects** (objective is to gain insights [basic research, applied research, methodology research]) = Type 1
2. **Projects for the development of new products and processes** (objective is the development of new marketable products/processes) = Type 2
3. **Projects for the enhancement of existing products (derivatives) and processes** (objective is the development of product enhancements (derivatives) and process enhancements, based on existing products and processes) = Type 3

## CONFIDENTIALITY

Your questionnaire will be treated with the **strictest confidentiality**. The results are published in aggregated form only, ensuring that **no inference can be drawn on participating companies**.

## RESPONSE

Please **send** or **fax** the completed questionnaire to:

*Fachhochschule Ludwigshafen*

**Tel +49 621 5203 259**

*Kompetenzzentrum Innovation und  
Marktorientierte Unternehmensführung*

**Fax +49 621 5203 274**  
**[kasper@fh-ludwigshafen.de](mailto:kasper@fh-ludwigshafen.de)**

*z. Hd. Eric Kasper*

*Ernst-Boehe-Str. 4*

*D-67059 Ludwigshafen*

**We thank you for and appreciate your contribution to our research project!**

**If you have any questions, please do not hesitate to contact us!**

**A. Types of R&D Projects**

**A1.** Your projects are characterised as having a very high **degree of innovation** (e.g. new organisational flows, new processes, new knowledge etc.).

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**A2.** During the implementation of your projects, **problems** occur because of the **complexity** of tasks (problems of coordination, structuring or transparency).

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**A3.** Project results are normally used by **more than one internal client** (company departments/divisions/business units).

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**A4.** Between the individual **projects**, there is a very **high technological ‘overlap’**.

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**A5. What percent of project objectives, resource needs (man hours, etc.) cannot be determined before the project actually begins (degree of uncertainty)?**

Project Type	100%-81%	80%-61%	60%-41%	40%-21%	20%-0%
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**A6. In general, how long do projects last from inception to dissemination of results?**

Project Type	more than 8 years	6 - 8 years	4 - 6 years	2 - 4 years	up to 2 years
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**A7. On average, what are the expenditures for specific infrastructure (e.g. specific laboratory equipment) as a percentage of the overall project expenditures?**

Project Type	100%-81%	80%-61%	60%-41%	40%-21%	20%-0%
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**A8. The knowledge needed for the implementation of projects is generally explicit (rather than tacit).**

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**B. R&D Organisation**

**B1. How is the level of the R&D budget determined in your company?**

(top down = derived from aggregated data (turnover, earnings), bottom up = summation of planned project costs)

Project Type	Top Down	Rather Top down	Both/ Top Down and Bottom Up	Rather Bottom Up	Bottom Up
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**B2. How will it be decided on, as to which projects from the pool of project proposals, are selected?** (decision of project planning: centrally = by the group, decentrally = by divisions/ business units/marketing companies)

Project Type	Only Central	Rather/ Somewhat Central	Both/ Standardised and Not Standardised	Rather Decentral	Only Decentral
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**B3. From an organisational perspective, which and to what extent are these R&D project types carried out centrally or decentrally?** Please indicate the percentages.

Project Type	Centrally	Decentrally (divisions/ business units/ marketing companies)	Total
• Type 1	_____%	_____%	100%
• Type 2	_____%	_____%	100%
• Type 3	_____%	_____%	100%

**C. R&D Resource Allocation**

**C1.** Which percentage of the R&D budget is determined by the **interaction of supply** (R&D units) and **demand** (divisions/business units/marketing companies), **without interference of a central committee?**

Project Type	100%-81%	80%-61%	60%-41%	40%-21%	20%-0%
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C2.** Which percentage of the budget share mentioned in question **C1.** is determined by **direct requests** from **development units?**

Project Type	100%-81%	80%-61%	60%-41%	40%-21%	20%-0%
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C3.** Which percentage of the budget share mentioned in question **C1.** is determined by **direct requests** from **units that are ‘closer’ to market** (divisions/business units/marketing companies)?

Project Type	100%-81%	80%-61%	60%-41%	40%-21%	20%-0%
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C4.** Who finances which part of the **R&D budget?** (percentage values according to the last accounting period)

Project Type	Company	Divisions	External	Total
• Type 1	___%	___%	___%	100%
• Type 2	___%	___%	___%	100%
• Type 3	___%	___%	___%	100%

**C5.** Those who have financed the projects **acquire the exclusive marketing and disposition rights** of the project results.

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C6.** Is it possible in your company to request money from an **internal (venture) fund**? If NO, please skip to question C9.

Project Type	Yes	No
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>

**C7.** If your answer to question **C6.** was **yes**, what **share is financed** by such a fund in relation to the R&D budget?

Project Type	
• Type 1	_____ %
• Type 2	_____ %
• Type 3	_____ %

**C8.** If your answer to question **A6.** was **yes**, how does the **filing of application** proceed as to **form, frequency, content and structure**?

Project Type	Standardised	Rather/ Somewhat Standardised	Both/		Not Standardised
			Standardised and Not Standardised	Not Really Standardised	
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**In your R&D units, how are the following decisions reached? (Questions C9. & C10.)**

**C9. Determination of staff capacity** (e.g. authorisation of new positions)

R&D Units	Only Central	Rather/Somewhat Central	Both/Neither Central or Independent	Rather Independent	Only Independent
• R&T Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Dev. Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C10. Determination of investments in infrastructure**

R&D Units	Only Central	Rather/Somewhat Central	Both/Neither Central or Independent	Rather Independent	Only Independent
• R&T Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Dev. Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C11. The expertise of both the R&D units and employees is recognised throughout the company.**

R&D Units	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• R&T Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Dev. Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C12. R&D services can be purchased from external providers.**

R&D Units	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• R&T Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Dev. Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C13. Your R&D units can offer their expertise to external users.**

R&D Units	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• R&T Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Dev. Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C14.** If any projects are decided upon by supply and demand, **who** initiates those projects? (in %)

Project Type	Demanders		Total
	Suppliers (R&D units)	(divisions/ business units/ marketing companies)	
• Type 1	_____%	_____%	100%
• Type 2	_____%	_____%	100%
• Type 3	_____%	_____%	100%

**C15.** In the case that the projects are initiated by the demand side, **from where** do the **initiators** of project ideas get the necessary **money**?

Project Type	Own Division	Other Division	Company	Internal Venture Fund	External
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C16.** **Initiators** of project ideas **push** these ideas by means of ‘**success stories**’ in order to **get the financing of project ideas**.

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C17.** How are **project ideas initiated** in your company?

Project Type	From Intranet Project-database	Written Application/ Filing	Oral Application/ Filing
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C18. Aspects of nondisclosure** impede the posting of project ideas, by means of an intranet-database.

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C19. If the project results are used by more than 1 internal client, do the internal clients have to pay for the use of the project results?**

Project Type	Yes	No
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>

**C20. How are directly-requested project-services charged?**

Project Type	Over/ Through Transfer Prices	Over/ Through Negotiated Prices	Over/ Through Market Prices	No Settlement
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C21. In your opinion, how should the prices for R&D projects/services be established in an internal market?**

Project Type	Through a Standardised Auction (i.e. in the Intranet)	Through Formal Negotiations (between the parties involved)	Through Informal Negotiations (between the parties involved)
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**C22. In case of an auction in the intranet: Who should be responsible for the design of the auction (form, guidelines, conditions etc.)?**

Project Type	Independent Committee	Supplier/ Provider (R&D Units)	Demander/Requestor (divisions/business units, etc.)	Both Supplier/ Demander
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**D. Allocation Result**

**D1. Direct assignments of divisions/business units etc.** lead to a **better achievement of objectives**, in comparison with projects predetermined by committees (more effective selection).

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**D2.** The allocation of project resources by supply and demand leads to an **improved adaptability** to changes in the environment, and thereby to a **more flexible resource control** (e.g. reaction to changed customer needs).

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**D3.** The allocation of project resources by supply and demand leads to a **shorter resource allocation process** (from the filing of application until the distribution of funds).

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**D4.** The allocation of project resources by supply and demand leads to **lower coordination costs** (e.g. costs for communication, coordination, planning, administration, etc.).

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**D5.** The allocation of project resources by supply and demand leads to **lower motivation costs** (e.g. for incentive systems, control, etc.).

Project Type	True, all of the time	True, some of the time	Indifferent	Rarely True	Not True, never
• Type 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Type 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**E. Supplementary Questions**

**E1.** What is the **R&D-to-sales ratio** of your company? \_\_\_\_\_%

**E2.** What was your approximate **R&D budget** in 2001 for the following project types? (in million Euro):

- Project Type**
- Type 1 \_\_\_\_\_ m. €
  - Type 2 \_\_\_\_\_ m. €
  - Type 3 \_\_\_\_\_ m. €

**E3.** How many **people** did you employ **in R&D** in 2001? \_\_\_\_\_

**E4.** Company:

Name \_\_\_\_\_

Industry \_\_\_\_\_

Company unit \_\_\_\_\_

Contact person \_\_\_\_\_

Address \_\_\_\_\_

Telephone/Fax \_\_\_\_\_

Email \_\_\_\_\_

## Appendix 3 – Abstract

In times of global markets, increasing competition and shorter product life cycles the effective and efficient management of industrial research and development (R&D) activities is of central importance for companies as well as for the whole economy. The efficient allocation of scarce R&D resources is therefore one of the central challenges for each company. This is especially true for the allocation of human resources and budgets on R&D projects. But, how could and should scarce resources be allocated on competing R&D projects? This thesis sets out to answer this question based on the findings of a research project which was supported and financed by the German Federal Ministry of Education and Research (reference no. 01 HW 0194).

Traditionally the resources for R&D projects are allocated via planning- and budgeting procedures, evaluation methods and hierarchical decision-committees. An alternative to such hierarchical decision procedures is the resource allocation via internal markets. Previous studies have mainly been concerned with hierarchical forms of R&D resource allocation, but they disregarded the potential of implementing internal R&D markets. Thus, this research was designed as an exploratory study to investigate whether internal R&D markets can add value to the R&D activities of companies. The thesis in hand therefore makes the following major contributions to the state of the art of R&D resource allocation:

- First of all it reveals fundamental differences across R&D project types concerning the project characteristics, the R&D organisation, the R&D resource allocation and the allocation result.
- Then it shows for which types of R&D projects market-driven forms of resource allocation are possible.
- Moreover, it illustrates for which types of R&D projects market-driven forms of resource allocation are more effective and/or efficient than hierarchical forms of resource allocation.
- Finally, it presents policy recommendations for the design of internal R&D markets in practice.

To ensure a uniform understanding of the term ‘internal R&D market’ a conceptual framework was developed, which served as the basis for the implementation of the empirical studies. Within the scope of the underlying research project a sequential triangulation of research methods was used, including case study research, survey research, and group interviews. The major advantage of this mixed-method approach is the greater validity and reliability of the presented research results.

The empirical results show that market-driven forms of resource allocation are not an established standard in the R&D field. Particularly the resources for Research & Technology projects, which aim at new businesses and markets, are predominantly allocated hierarchically via centralised decision-committees. Market-driven forms of resource allocation on the other hand are mainly applied and recommendable for enhancement and new development projects as well as for Research & Technology projects aimed at existing businesses and markets. As outlined in the policy recommendations, the effectiveness and efficiency of internal R&D markets strongly depend on the project characteristics and the organisational arrangements. The higher the degrees of routine, certainty and short-term commercialisation, and the higher the degree of organisational decentralisation, the more recommendable is the application of internal R&D markets. But, how should an internal R&D market be designed? To answer this question the policy recommendations provide an evaluation model which supports R&D managers in the actual design of an internal R&D market.

In summary, the ‘novel’ findings of this study show that there are project type-specific differences concerning the applied form of R&D resource allocation. Moreover, the implementation of internal R&D markets appears to have positive effects on the effectiveness and efficiency of internal R&D resource allocation processes. Furthermore, internal R&D markets can help to overcome the weaknesses of traditional hierarchical structures, since they are characterised by short communication and decision procedures and thus contribute to the reduction of information asymmetries. In conclusion, this thesis has made significant contributions to the state of the art of innovation management, respectively, R&D management. Moreover, the presented work constitutes a sound base for future research activities in this area.

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