Collaboration Formation in Virtual Organisations by applying prospective Performance Measurement

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Dissertation

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Preface

The present book is the translation of my dissertation which was already published in 2007 (ISBN 3-86130-529). Due to many requests from foreign project partners and interested parties it has now been put into English. I sincerely thank Mr. Felix Römer for the present translation done with diligence and endurance.

This dissertation evolved from and during my occupation at the Bremer Institut für Produktion und Logistik - BIBA, University of Bremen. Here and through the experience gained in numerous international research projects and conferences, I had the opportunity to develop my topic and discuss my approaches with an international audience of experts.

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Bremen, January 2009
1 Introduction ......................................................................................................................... 1
  1.1 Motivation ................................................................................................................... 1
  1.2 Problem ....................................................................................................................... 2
  1.3 Purpose and Procedure of the Dissertation .............................................................. 3
  1.4 Structure of the Dissertation ..................................................................................... 3

2 Collaboration Formation in Virtual Organizations ............................................................ 7
  2.1 Characteristics and Forms of Networking ................................................................... 8
  2.2 Characteristics and Definitions of Virtual Organizations ........................................ 12
  2.3 The Initiation of Virtual Organizations .................................................................... 13
    2.3.1 Structuring the Initiation Phase ........................................................................ 15
    2.3.2 Approaches to Collaboration Formation within the Initiation Phase ............... 18
  2.4 Industrial Examples of Virtual Organizations .......................................................... 19

3 Performance Measurement as Approach to the Evaluation of Virtual Organizations .......... 25
  3.1 Existing Approaches to the Evaluation of Company Collaborations ......................... 26
    3.1.1 Performance Measurement ............................................................................. 27
    3.1.2 Simulation ...................................................................................................... 30
    3.1.3 Expert Systeme ............................................................................................... 33
  3.2 Principles of Performance Measurement ..................................................................... 35
    3.2.1 Origin and Definition ...................................................................................... 36
    3.2.2 Available Approaches to Performance Measurement and their Typologies ....... 40
    3.2.3 IT-Support of Performance Measurement ..................................................... 43
  3.3 Requirements on a Performance Measurement for Virtual Organizations ................ 46
    3.3.1 Necessity of the Prospective Evaluation of Virtual Organizations through Performance Measurement ................................................................. 46
    3.3.2 Criteria for the Selection of a Performance Measurement Approach ................. 51
    3.3.3 Requirements on the IT-Support of the Performance Measurement in Virtual Organizations ................................................................. 52
  3.4 Appropriateness of available Performance Measurement approaches for Virtual Organizations ................................................................. 54
3.4.1 Attributes of the SCOR-Model as Concept for the Evaluation of Inter-Organizational Process Chains .......... 55
3.4.2 Approaches for the Utilization of the SCOR-Model in Company-Networks............................................................ 58
3.4.3 Applicability of IT-Systems for the Performance Measurement for the Support of the Collaboration Formation in Virtual Organizations.................................... 62

4 Conception of a Prospective Performance Measurement for Virtual Organizations .................................................................................................. 65
4.1 Management Tool .......................................................................................................................................................... 70
  4.1.1 Modeling of the Processes of Each Member of the Virtual Breeding Environment and Acquisition of their Possible Product Contributions ........................................... 70
  4.1.2 Acquisition of the Effectively Rendered Performance in the Operation Phase of a Virtual Organization ........... 72
4.2 Company Profiles ......................................................................................................................................................... 75
4.3 Planning Instrument .......................................................................................................................................................... 76
  4.3.1 Iterative Generation of the Bill of Material of the End Product to be realized and the Derivation of the Process Chain .......................................................................................... 77
  4.3.2 Identification of Possible Consortium Partners ......................................................................................................... 79
  4.3.3 Determination of Objectives for the Partner Selection .......................................................................................... 81
  4.3.4 Evaluation of the possible Consortia and Partner Selection .................................................................................. 83

5 Development of an IT-Based System for Prospective Performance Measurement ............................................................................................................................................. 93
5.1 Requirements Analysis .................................................................................................................................................. 95
  5.1.1 Basic Requirements .................................................................................................................................................. 96
  5.1.1.1 Application Type .................................................................................................................................................. 96
  5.1.1.2 Core Functions .................................................................................................................................................. 97
  5.1.2 Release Planning .................................................................................................................................................... 98
    5.1.2.1 Release 1: Company Configuration and the Data Acquisition (Management tool) ................................................. 99
    5.1.2.2 Release 2: Identification of Possible Consortia and their Analysis (Planning Instrument) ......................................... 100
5.2 System Design ............................................................................................................................................................. 101
  5.2.1 Architecture Design ............................................................................................................................................... 101
  5.2.2 Release 1 ................................................................................................................................................................. 102
    5.2.2.1 Content Modeling ........................................................................................................................................... 102
    5.2.2.2 Hypertext Modeling ........................................................................................................................................ 105
## 1 Introduction

5.2.3 Release 2 ................................................................. 108  
5.2.3.1 Content Modeling .................................................. 108  
5.2.3.2 Hypertext Modeling .............................................. 110

5.3 Implementation .......................................................... 111  
5.3.1 Utilized Technologies ............................................... 111  
5.3.2 Release 1 ............................................................... 112  
5.3.2.1 User and Company Administration .......................... 112  
5.3.2.2 Process Reference Model ....................................... 117  
5.3.2.3 KPI-Acquisition .................................................... 119  
5.3.2.4 Product Catalogue ............................................... 122  
5.3.2.5 Additional Functions ............................................. 124  
5.3.3 Release 2: Identification and Analysis of possible Consortia ........................................... 125

## 6 Evaluation......................................................................................... 129

6.1 Presentation of an Example Case ........................................... 129  
6.2 Possibilities and Limits of the Performance Analysis of the Example Case in the Application of SCOR-Cards ......................... 132  
6.3 Consortium Planning through Prediction of the over-all Performance of Possible Consortia ................................................ 134  
6.4 Discussion and Results of the Evaluation ................................. 144

## 7 Conclusion and Outlook................................................................. 145

## 8 List of Literature.............................................................................. 148

Appendix A ......................................................................................... 154

Appendix B ......................................................................................... 161
1 Introduction

The successful existence of producing enterprises in global competition increasingly requires the range of customized products. Over the last few decades, growing complexity of these products has caused that at present, capital intensive and complex goods are predominantly consortium achievements of various companies. Each involved consortium member focuses on its own core competencies, and through collaboration they altogether create the necessary diversity of processing. By the latest since the nineties, competition does not any longer take place between single companies, but between contractor consortia (Boutellier 1999, p. 66). Hence, today, the ability to establish an excellent consortium is an important competitive advantage.

1.1 Motivation

From the economic point of view, the beginning 21th century is globally marked by further globalization and deregulation of markets. For example, increasing harmonization of the European Union as well as falling trade barriers around the world promote global, entrepreneurial action on a worldwide input, and output market. For the first time, enterprises have almost absolute access to resources, customers, and developed local markets from all around the world. Nowadays, it is in principle possible, to configure expertise needed for a contract order-specifically, by integrating the world-wide best suited partners in one consortium. In the past, collaborations were arranged to be long-term co-operation in form of fixed consortia. In turn in future, they will increasingly become temporarily arrangements; in extreme examples, they could even be established to fulfill only one contract. In literature, this form of temporarily set, dynamic collaboration of usually equal partners independent in law is called Virtual Organization (Sydow 2002, p. 270).

Unlike stable supply chains, process chains in Virtual Organization are not anymore determined at long range by available competencies of fixed partnerships. Process chains of Virtual Organization can always be newly configured according to the specific requirements of its actual contracts. The network configurator has to be able to identify the required competencies and capacities in the moment of the order placing, and also, he must be capable of including these competencies and capacities into a suitable, temporary consortium. The composition of the consortium—in other words the selection of partners- has a significant impact on the possible potential of the Virtual Organization (Kemmer 1999, p.33). The ability to activate the individual consortium proficiency as fast as the proficiency of a single enterprise is the prime challenge, setting up a Virtual Organization. Looking ahead, the maintenance of one’s collaborational environment, with a view to forming a collaboration network quickly, will be a permanent duty of enterprises. This maintenance can be examined from two different positions. On one side, it can be surveyed from the position of a potential consortium partner that offers its competen-
cies, and that wants to contribute said, and on the other side it can be surveyed from the position of the network configurator, who must identify and establish adequate partnerships for a given request. This network configurator might be the prime contractor, called the Lead-Partner, or as well a neural instance.

1.2 Problem

The bases of collaboration in Virtual Organizations are integrated and configurable process chains. The fast establishment of process chains within frequently changing consortia, and therefore short reaction times to market demands is an important qualification for operating a Virtual Organization. Hence, the individual enterprise as an potential consortium partner must face the problem that it’s resources that can only be influenced in the long- or middle-term must be rapidly brought in new consortia as profit generating contributions in short-term. Among these resources are sites, available capacities, and the present qualification profile of the personnel. It results, besides the control over intra-firm proceedings, contributions to powerful cross company process chains are major success factors of Virtual Organizations.

Today’s methods and tools to estimate capacity or rather the performance of business processes are summed up by the idea of Performance Measurement. The constant data collection and observation of rendered operational performance through Performance Measurement serves the purpose of regular weak-point analyses, and is essential to continuous optimization of the process chain. This means, Performance Measurement is used for the retrospective analysis and improvement of a performance given in the past, and acts as a tool of supervision and management. Performance Measurement only allows retroactive reaction to measured symptoms. In order to improve processes on the basis of observations, the processes as well as the consortium itself must be sufficiently stable in all its compounds.

By reason of its contract-specific organizational line, retrospective evaluation of process chains is little suggestible for Virtual Organization. In extreme cases, a collaboration must prove its abilities in its very first contract, because it has only been formed to fulfill this one agreement. In this particularly dynamic environment of changing partnerships, continuous, long-term optimization is no longer possible. So, it is necessary to estimate the performance of a planned consortium, before its actual establishment, so the most qualified and adequate consortium partners can be selected in time. The application of available Performance Measurement approaches to Virtual Organization is barely recommendable, because of its retrospective structure. Today, there is no approach to prospective estimation process-performance of projected consortia. Thus, its development is the subject of this paper.
1.3 Purpose and Procedure of the Dissertation

Goal of this paper is the conception and information technical (IT) realization of a prospective Performance Measurement in order to support collaboration formation in Virtual Organizations. Important aspects of the conception are the identification of possible consortia that make a certain end product achievable, and the estimation of the performance to be expected of these possible consortia. The method to be developed is meant to support the business partner selection yet in the initiation phase of collaboration, and is based on the forecast performance of the planned consortium. Later in the thesis, available alternatives of business partner selection are described, and their influence on the forecast performance of a planned consortium is estimated. The early knowledge of possible alternatives is decisive to grant Virtual Organization the permanent capacity to act (that is bargaining and delivery capacity), even if a partner fails. Through the identification and comparison of consortium alternatives for the realization of an end product, the expected performance along the whole process chain is to be forecast in order to determine the optimal consortium variant for this contract execution. The business partner is selected from a pool of known companies that are principally collaboration-willing.

The configuration of consortia is done in three steps. Firstly, the bill of material of the end product to be realized must be generated through the identification of possible product contributions. The outcome of the combination of proper processes on different value creation levels is a process chain, fitting for this specific bill of material. Finally, different consortia can be built through variations on basically fitting consortium partners. While combination, which is the product-specific linkage of single processes to a process chain, is derived from the bill of material of the end product to be realized, variation describes possible alternatives of the selection of consortium partners.

To start with the prospective evaluation of an identified consortium, the expected performance of the consortium partners is forecast in reference to those processes within the process chain that are executed by respective consortium partners. These performance forecasts of every single consortium partner are finally aggregated to the Over-All Performance of the consortium. This Over-All Performance of a consortium serves as the evaluation and therefore comparison of possible consortia, and ultimately the business partner selection.

1.4 Structure of the Dissertation

Figure 1 displays the logical structure of this paper. In chapter two, the foundations of Networking are defined, leading to the task definition of Virtual Organizations. In doing so, also, the procedure of collaboration formation is identified as the crucial phase for the formation of high-performance Virtual Organizations. Chapter 3 presents existing approaches of collaboration evaluation in section 3.1, and then gives reasons for the choice of Performance Measurement as the methodic ap-
1 Introduction

proach of this paper. Later, it enlarges on the basis of Performance Measurement, introduces and typologizes fundamental Performance Measurement approaches of Virtual Organizations, and names ways of IT-application of Performance Measurement.

In section 3.3, conceptual and technical requirements of Performance Measurement for Virtual Organizations are recognized and the necessity of prospective Performance Measurement is demonstrated. Thereafter, section 3.4 investigates the applicability of introduced Performance Measurement approaches for Virtual Organizations. For this, the SCOR-Model is chosen as initial point for Performance Measurement, but it is also checked for its capacity.

On basis of the point of interest elaborated in chapter 3, chapter 4 then initiates the development of a Performance Measurement approach to support collaboration formation in Virtual Organizations. Method development is divided into three areas, as following: Management Tool (4.1) Company Profile (4.2), and Planning Instrument (4.3).

Chapter 5 describes the prototypical implementation of the method as software.

Chapter 6 covers the evaluation of the method by means of a constructed case example.

Chapter 7 concludes the paper, and gives an outlook on some of the possible next steps, which are partly already development objectives of current research projects.
Figure 1: Structure of the Thesis
1 Introduction
2 Collaboration Formation in Virtual Organizations

The industrial production of complex, capital intensive products is carried out along process chains, composed of consortium contributions of different companies. This form of division of labor is derived from the principle of core competencies. According to this principle, single processes are assigned to the most suitable partner. In past times, this kind of collaborations, so-called supply chains, was of long duration and based on inflexible vendor-costumer relationships with long-term contractual engagements. Over the last few years of increasing complexity of products as well as easily accessible global resources, all indicators are that collaborations are more and more deliberately designed for the short run. An example is the Virtual Factory Euregio Bodensee, a voluntarily agreement of 30 collaboration-willing companies, with the common aim to offer comprehensive total solutions through dynamic combination of individual performance, in that way that the end product is perfectly specified to respective customer wishes (see section 2.4). Unlike stable supply chains, this form of cross company collaboration is best characterized by the principles of contract-orientation, causing temporarily composition of the consortium, and networking of collaboration-willing companies.

Search and selection of business partners, in other words the collaboration formation itself, plays a decisive role in temporary consortium collaborations, because, here, the opportunity of a long-term harmonization of cross company business processes is not given. In consequence, consortia must be ideally compounded and capable of acting from the very beginning. This is why, besides the selection of the most suitable partner, also the knowledge of alternatives to consortium partners is crucial, for example, for the fast compensation of a key partner’s shortfall. Because, only if the alternatives are known and calculable while the partner selection, contingency risk can be cushioned, and capability of acting can be assured at short notice.

In literature, and within the scope of networking, collaborations with a high level of dynamism in the composition of the consortium are often called Virtual Organizations. Concepts of networking have been subject of scientific discussions for about 15 years, and slowly establish themselves in industrial practice. A uniform comprehension with a binding typology of networking hasn’t been developed yet. (Camarinha-Matos 2005, p. 4)
2.1 Characteristics and Forms of Networking

The rationale of networking is based upon the (voluntary) collaboration of independent companies, with the objective of taking certain advantages of the collaboration, while maintaining their basic commercial independence (Schierenbeck 1995, p. 49). There are a large number of different names for this form of collaboration between companies, however, there is no clear typology. The criteria used in this context lead almost always to problem-specific task-definitions. Nevertheless, there is consensus for the most part on the description of the main objective of collaborations. This is due to the fact that competencies as well as economical relationships of the involved partners complement one another in order to achieve a better position in competition for all consortium partners. Ideally, competencies of the respective service providers complement one another along the value chain to that degree that every phase of the process has got its own specialist (Nyhuis 2005). The ultimate principle of collaboration is the synergy effect. It is the assumption, that the common capacity is greater than the sum of individual performances. Following criteria for the typology of operational collaboration are commonly used in literature (Albers 2000 p. 9; Bronder, Pritzl 1999, p. 30ff; Hess 2002, p.11; Nyhuis 2005):

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>e.g., Science and development, supply and purchase, production, marketing, sale und distribution, service, dismantlement and recycling</td>
</tr>
<tr>
<td>Direction of the collaboration</td>
<td>horizontal (between enterprises of the same production or market stage), vertical (between enterprises of different production or market stages)</td>
</tr>
<tr>
<td>Intensity</td>
<td>e.g., exchange of experiences, role and responsibility coordination or common examinations, planning and optimizations of the value chain</td>
</tr>
<tr>
<td>Origin of the partners</td>
<td>local, regional, national, global</td>
</tr>
<tr>
<td>Number of partners</td>
<td>bilateral or multilateral</td>
</tr>
<tr>
<td>Commitment of the partners</td>
<td>informal (agreements und regulations), contractual</td>
</tr>
<tr>
<td>Market access</td>
<td>One member, various members, all members</td>
</tr>
<tr>
<td>Number of products</td>
<td>One product (possibly multiple variants), several products</td>
</tr>
<tr>
<td>Power structure</td>
<td>Hierarchical (focal enterprise), heterarchical (polycentric)</td>
</tr>
<tr>
<td>Duration of the partnership</td>
<td>Short-term (dynamic), medium-term (semi-static), long-term /open-ended (static)</td>
</tr>
</tbody>
</table>

Table 1: Criteria for the typology of operational collaborations (Nyhuis)
Sydow (Sydow 1998, p. 16) deploys two criteria for the typology of collaboration, namely *power structure* and *duration of partnership*, and derives a cross matrix (figure 2) from the manifestations of these criteria. Here, duration of partnership describes the temporary aspect, or so to say the stability of collaboration, and power structure qualifies the form of control of the collaboration. It can be either hierarchical, so that one partner assumes the leadership (called Lead-Partner), or heterarchical with various equal partners. Taking these two criteria as a basis, it can be observed that innovative concepts of collaboration are increasingly characterized by shorter duration of partnership, and therefore rising dynamism of partnership (Kramer 1998, p. 19). With decreasing duration of partnership, the process of collaboration formation becomes an essential success factor for collaborative production.

An explanation for shortened Durations of Collaboration was given by Reichwald and Goecke, who referred to growing complexity of products as well as to rising market insecurity. The coherency between these developments and networking is pictured in figure 2.

![Figure 2: Tendencies of networking as a consequence of higher product complexity and market insecurities (Reichwald, Goecke 1996, p.87)](image-url)
Because of growing complexity of products and rising market insecurity, Reichwald and Goecke see a turn away from traditional hierarchical organizations, and a turn towards company networks in form of strategic alliances, and Virtual Organizations. In the case of products with low complexity and high market insecurity, companies tend to engage themselves in strategic alliances or joint ventures, while the case of high product complexity linked with high market insecurity implicates the formation of so-called Virtual Organizations. Typical products of high complexity linked with turbulent markets are cost-intensive investment goods that usually even are unique products.

For the classification and the differentiation of the idea of networks, Sydow discriminates between Regional Networks, Project Networks, Strategic Networks, and Virtual Organizations, and he uses the cross matrix displayed in figure 3. Form of control and stability of network configuration are the two significant criteria used for the classification. Through the introduction of these criteria, discrimination takes place between static and dynamic (viz. long-term and short-term) networks, and hierarchical and heterarchical networks.

Figure 3: Cross matrix for the discrimination of network types according to Sydow (Sydow 1998, p. 16)
Sydow characterizes networks as principally “complex-reciprocal” and “rather collaborative than competitive” relationships between several economically dependent companies independent in law (Sydow 2002, p.79). Unlike traditional supply chains, networks are based on a multilateral linkage of relationships between the individual partners among each other. Also, they are connected by a common basis of values (Kramer 1998, p. 17).

**Strategic Networks** are led hierarchically by at least one company. This so-called Lead-Partner determines, more than other partners, the markets to be supplied, and the strategy and technology to be chosen. The partnership in this network type is usually planned to last long, and allows a continuous improvement of common processes. In literature, collaboration in Strategic Networks is often limited to the co-operation in a certain business segment. Business-segment-specific collaboration is only possible between current or at least potential competitors, so, as a consequence, Strategic Networks must be viewed as compellingly horizontal collaborations (Hess 2002, p. 12). Other authors argue, there is no such limitation to one business segment for the achievement of a common competitive advantage in Strategic Networks (Krieger 2001, p.17). Therefore, also vertical Strategic Networks are possible.

**Regional Networks** consist of small and middle-class businesses, and in contrast to Strategic Networks, they are marked by geographical closeness of partner companies. The heterarchical or polycentric organization of the regional networks usually works without network leadership, and it benefits from the advantages of short distances.

**Project Networks** are best characterized by its temporary limitation. The fluctuation of members is very high. New projects tie in with existing relationships, but they also form completely new partnerships. Project networks are mostly led hierarchically by a Lead-Partner, but there are also Project Networks with a heterarchical power structure.

**Virtual Organizations** are marked by a high dynamism in the configuration of partnerships. Thanks to globally developed markets, today, companies have worldwide access to resources, and their ability to make offers is no longer limited by existing static business relationships, nor market limitations and regulations. For this reason, now, companies have the opportunity to flexibly compile resources that are needed for a specific contract, and commit themselves dynamically to partnerships. In Virtual Organizations, just like in Project Networks, consortia are formed for the duration of a specific contract. Concerning a differentiation into hierarchical or heterarchical structures, Sydow keeps his options open. So, the control of Virtual Organizations can either be exercised by a permanent primary Lead-Partner, or is derived from new contracts. In the second case, all partners are principally equal. This is why the partner directly linked to the customer or a neutral
instance acts as Lead-Partner. The Formation of Virtual Organizations steadily gains significance, therefore, it is subject of many scientific works. The following section enlarges on Virtual Organizations as a form of collaboration.

2.2 Characteristics and Definitions of Virtual Organizations

In section 2.1, Virtual Organization was introduced as a suitable form of collaboration for the creation of complex products with high market insecurity. As a first classification on basis of the cross matrix, dynamism of collaboration and the tendency to hierarchy building were identified as structural attributes. To determine the task definition of Virtual Organizations, further representative attributes (Linde 1997, p. 40ff; Camarinha-Maos, p.15ff) can be consulted.

Dematerialization: Conventional product factors, such as real estate, work and capital, are more and more substituted by the factors information and knowledge.

Delocalization: Many Virtual Organizations free themselves from former geographic restrictions. The integration of individual function owners and resources is done by electronic data transmission. Therefore, the existence of modern information and communication technology (ICT) is a precondition for Virtual Organizations.

Detemporization: The narrowing down to core competencies of potential partners makes possible a increased velocity of the value creation process. The capacity of faster and high-efficient availability of a few processes leads to higher capacity to react as well as to lesser dependence on temporary restrictions. The objective of Virtual Organizations is to be able to act as quick as a single enterprise, despite of higher coordination efforts.

Function-orientation: The product is usually the primary focus for labor division in traditional collaboration. In Virtual Organizations, the desired performances result from the interaction of diverse functions that haven’t been connected previous to the contract award of the customer. Single enterprises don’t offer products, but they do offer functions that only generate products in connection with functions of other consortium partners.

Resource-Orientaton: Firstly, resources required for the performance rendition are not supplied by a direct procedure. Therewith, the control over the resources remains in the hands of the respective consortium partners. Secondly, also the core competencies of all involved companies that coalesce in Virtual Organizations are viewed as resources, because their application is still to be assigned.

Customization: With their products, traditional and hierarchical organizations aim at anonymous mass markets (see Figure 2). In contrast, Virtual Organizations compile individual goods and services, often even including unique goods and ser-
vices, according to the concrete needs of the consumer. Due to this, investment goods are one emphasis of production in Virtual Organizations.

Relativization of Borders: The system borders of Virtual Organizations vary, depending on the portfolio of available core competencies, because these resources are only engaged order-specifically, and when required.

In addition to these characteristics, Wüthrich phrases a quite comprehensive definition of Virtual Organizations. He describes Virtual Organizations as a “voluntary and temporary form of collaboration of several partners (companies, institutions, individuals) usually independent in law, who altogether render a high customer value, thanks to the optimized value creation. On basis of a common understanding of commercial procedures and a distinct culture of trust, the collaboration partners contribute their core competencies in form of resources or competencies, with the objective of becoming better, cheaper, faster, more flexible, and internationally more competitive (Wüthrich 1997, p.96)”. The setup and dissolution of collaborations happens fast and without the institution of a central coordination unit, and also without the negotiation of strictly specified contracts. The Virtual Organization exists until its business purpose is either fulfilled or invalid (Arnold, Oksana 1995). Consequently, a Virtual Organization can be understood as a business unit that emerges from the temporary integration of different core competencies to provide complex customer-specific goods and services fast and inexpensive (Linde 1997, p.25)

2.3 The Initiation of Virtual Organizations

Basically, the chronological course of every collaboration can be divided into three characteristic phases: The Initiation Phase, in which collaborations are planned and initiated, the Operation Phase, in which the actual performance rendition takes place, and the Dissolution Phase, in which the collaboration is dissolved or reconfigured. Regarding the collaboration formation in Virtual Organizations, Mertins and Faisst (Mertins, Faisst 1995, p. 61ff) supplement this classification and differentiate between three sub-phases of the Initiation Phase, and they call the temporal course the life phases of Virtual Organizations. Mentioned three sub-phases are Preparation, Search /Selection of Business Partner(s), and Agreement. Figure 4 shows the course of collaboration in Virtual Organization with its life phases.
Figure 4: Life Phases of Virtual Organizations (compare Thoben 2001, p. 428)

- Initiation Phase

The first step of this phase, the Preparation, is triggered by a concrete business opportunity, generally an inquiry of a customer. The initiative to set off the Virtual Organization, and therewith the role of the Lead-Partner, is usually assumed by that company that has direct customer contact. The Lead-Partner identifies competencies and processes required for the realization of the customer’s wishes in order to search and select suitable consortium partners.

In the second step of the Initiation Phase, the Search /Selection of Business Partner(s), the actual collaboration formation is carried out. This is not a one-time event, but, in the extreme case, and with the ideal realization of the respective contract requirements in mind, is reapplied for every new contract. Because the objective of collaboration formation is the establishment of powerful Virtual Organizations, the methodic search and selection of the most adequate partner plays a decisive role. In the course of the Partner Search, the Lead-Partner must begin with the identification of potentially adequate partner for different purposes, such as the product development and production, and probably other product life phases, like customer service and support or even the disposal of the product to be realized. The partner selection from this pool of potentially adequate partners requires different criteria and priorities for each purpose. Maybe, deliberately differing decisions for a consortium partner are necessary for every single purpose due to strategic reasons; For instance, by scattering the competencies along the product life phases, a drain-off of knowhow can be prevented. This is important, because consortium members are usually involved in several networks at the same time. For example, Nike lost its market leadership in sports shoes to other contractors, who drew their resources from that very network that Nike once set up, and that gradually obtained comprehensive product and process competencies (Edelmann 2000). Thus, already in an early phase of the Virtual Organization life cycle, not only its future achievement potential is determined (Höbig 2002, p.42), but also its long-term success can be influenced.
In the last step of the Initiation Phase, the Agreement, a framework agreement of collaboration between the consortium partners is composed. At this, rules of labor division, resource planning, and procedure harmonization are established, also, a common infrastructure, required for the coordination of collaboration, is determined. This agreement can either be designed democratically, or it can be dictated by the Lead-Partner, depending on the power structure of the Virtual Organization. The difficulty is to find an appropriate ratio between over-regimentation and insufficient regimentation, or, so to speak, a ratio between coordination efforts and flexibility within the Virtual Organization (Kramer 1998, p.29).

- **Operation Phase**

The Operation Phase represents the actual production of goods and services. Besides value creation processes, it mainly covers coordination functions, such as process control and process evaluation. When the business purpose is fulfilled, the Virtual Organization either dissolves or reconfigures itself (Zimmermann 1997). Compared to supply chains, the Operation Phase in Virtual Organizations is downright short. Usual methods like continuous process optimization during the Operation Phase are only applicable to a small extend, because they assume the stability of collaborations and processes.

- **Dissolution Phase**

In Virtual Organizations, the Dissolution Phase starts after the fulfillment of a concrete business purpose. Here, either the complete dissolution of the collaboration or the reconfiguration takes place. In the second case, a similar task directly follows the first collaboration. Object of the Dissolution Phase is the financial fulfillment of the contract or the agreement and probably also the return of resources (e.g. construction site projects) as well as the evaluation of possibilities for succeeding projects. In addition, responsibilities and modalities for the product support and product disposal must be fixed, due to legal regulations. On account of this, the Dissolution Phase may trigger the setup of service provider and disposal networks.

### 2.3.1 Structuring the Initiation Phase

The aim structuring the Initiation Phase of Virtual Organizations is to enable independent companies to instance a collaboration capable of bargaining and delivering on short call. Even if involved companies haven’t collected common experiences in collaboration yet, the newly formed Virtual Organization must react to market demands as fast as a single company.

Basis of collaboration, besides basic contractual provisions, are principles of the benefit- and risk- sharing, and technical and the organizational frame rules of col-
laboration structuring. In long-term collaborations, this basis can be established once, and then it will be continuously developed. However, in Virtual Organizations, the establishment of collaborations is a regular task. For this reason, it is an important requirement for the operation of Virtual Organizations to be capable of acting as a consortium after a short Initiation Phase. This means, the maintenance of one’s own collaboration environment is one of the prime duties and responsibilities in Virtual Organizations.

One approach to reach the ability to act or to collaborate quickly in Virtual Organizations is to carry out all order-independent activities before the realization of a concrete business option. For this, basically collaboration-willing companies settle on technical and organizational rules of collaboration as part of a collaboration agreement. If such a harmonization of potential collaboration partners is completed, the only thing left to do in case of an offer is to configure the Virtual Organization on basis of the established structures. In line with the European joint project “Ecolead” (www.ecolead.org), the concept “Virtual Breeding Environment” was developed to help the technical and organizational structuring of Virtual Organizations. The objective of “Virtual Breeding Environment” is the creation of structures that make accelerated reactions of Virtual Organizations to arising business options possible. Camarinha-Matos and Afsarmanesh describe the “Virtual Breeding Environment” as an”environment with the special purpose of allowing trust-building processes in scenarios characterized through agility and dynamism” (Eschenbächer 2005, p.118).
While a concrete business option triggers the Initiation Phase in conventional collaborations (compare figure 5, path 1), the “Virtual Breeding Environment”-concept is based on a division of the Initiation Phase into preparation of collaboration (order-independent) and into instantiation (order-dependent). Basic market opportunities are the cause for collaboration-willing companies to establish common structures in form of a “Virtual Breeding Environment” (figure 5, path 2a). The companies want to be capable of collaborating and therefore delivering quickly in the case of an award of an order. Objects of this preparation of collaboration are the integration of potential collaboration partners through collaboration agreements for the creation of a common understanding of business, the design of a common information and communication infrastructure and the agreement on principles of benefit- and risk-sharing. The application of efficient ICTs principally benefits the integration of geographically scattered companies and is therefore viewed as an important requirement for Virtual Organization building (Eschenbächer 2005, p.119). In event of a concrete business option, the instantiation of the Virtual Organization is made by the Lead-Partner, starting with the “Virtual Breeding Environment” (figure 5, path 2b). Because common structures...
already exist, reaction times of Virtual Organizations to business options can be significantly reduced. Within collaboration formation, the Lead-Partner must firstly identify all potential consortium partners in the “Virtual Breeding Environment” for the current job, and then he must select the most suitable partners. Finally, the common technical infrastructure for the planned consortium must be configured.

### 2.3.2 Approaches to Collaboration Formation within the Initiation Phase

For the procedure of collaboration formation, the activities business partner search and business partner selection were identified. In the context of the business partner search, Zahn calls **one's own corporate circle of acquaintances** the main source for consortium partners, without quantifying his empirical conclusion (Zahn 2001, p. 60). Companies trust in continuing already tried and proven collaborations with their suppliers when it comes to a business partner selection. The agreements over collaboration often even result from private contacts of the business partners (so-called golf course cronyism, Höbig 2002, p.43). Hence, as a general rule, the business partner selection isn’t done on the background of the overall optimum for the Virtual Organization, but on the maintenance of proven bilateral business relations. The advantage of choosing a company with that one already has business relations is the already existing mutual trust. Disadvantage of this approach is the limitation to a very small pool of companies to choose from. Therefore, it is unlikely to find the ideal business partner for the task requirements. Zahn spots the danger of selecting a suboptimal business partner, because of respect for bilateral business relations or long-time friendships (Höbig 2002, p.43).

As an alternative, **Collaboration Databases** and **Information Brokers** are suggested in literature (Kramer 1998, Zahn 2001). Collaboration Databases are based on the web and equate to public virtual networking services. Principally collaboration-willing companies can register in the database with their own Company Profile and/ or specifically search for companies that meet certain search criteria in an “open universe of companies” (compare to figure 5). Through this, a preliminary selection is rendered possible. Zahn presents a selection of today’s Collaboration Databases that are available in practice (Zahn 2001, p.63). However, the big number of parallel run Cooperation Databases on the market and often sparse information about registered companies make the search long and hard. Kramer proposes web-based catalogues with Information Brokers in order to ease the search for a suitable business partner through databases and to improve the quality of search results. In these catalogues, companies are listed by their core competencies and automatically identified through the Information Brokers, who overlook the depth of information (Kramer 1998, p. 29).
All introduced approaches principally support companies to search and select suppliers and single core competencies. Nevertheless, the planning of complete consortia on basis of a “Virtual Breeding Environment” as well as the identification and analysis of planning alternatives isn’t possible with these approaches.

### 2.4 Industrial Examples of Virtual Organizations

An important aspect of collaboration formation is the power structure of the Virtual Organization to be built. It derives from the way of control, who should take the initiative of initiating the Virtual Organization, and who should make concrete requirements on consortium partners to be selected. Depending on the character of the Virtual Organization, this can be a company with permanent Lead-Partner-function (hierarchical Virtual Organization) or a Lead-Partner that is designated due to a concrete order (tending to be heterarchical Virtual Organization).

In this section, different manifestations of the criterion power structure are presented by means of examples of industrial realization of Virtual Organizations. Then, these examples are classified via the cross matrix of Sydow. On basis of this, the relation between power structure/stability and the procedure of collaboration formation is discussed. Gained knowledge finally serves as the basis for the concept development for this paper.

- **Lewis Galoob Toys**

  “This US-American producer of toys has little over 100 salaried employees, and it already marketed 50 million $ worth of goods in the eighties (1985). Yet in the early nineties, Galoob bought product ideas from independent inventors and let freelance engineering offices do the product development. The actual production is done by a sub contractual company in Hong Kong. Again, this company sourced out labor intensive functions to [the mainland of] China. The end products are transported to the USA by forwarding agents and then distributed by freelance contract representatives. Even functions like factoring and financial accounting are conducted by independent service industries. Galoob basically limits itself to the strategic leadership of a network of independent companies, and therefore acts as the lead-company” (Arnold, Faisst 1995, p.8-23)

- **TelePad Corp.**

  “The TelePad Corp. was founded by Ron Oklewicz, a former employee of Xerox and Apple, as a focal point for Virtual Organizations. His goal was to develop and launch a novel computer, that would be particularly small, and that could be operated with a pen. TelePad hardly had competencies in the area of product design, no production capacities, and only a few engineers at its disposal. The computer was developed together with GVO Inc., a big industrial design company. A team of the Intel Corp. solved various technical problems, while other
firms wrote the software for the computer, and a producer of batteries helped TelePad to solve problems of the power supply. For the production, free capacities in an IBM-factory in Charlotte, N.C. were used. Oklewicz himself contributed his special knowledge in selling computers to governmental authorities to his Virtual Organization that consisted of all-in-all two dozen companies. Over 1000 specialists of the areas design, production, and to the point of marketing took part in the Virtual Organization. None of the involved people could have developed or launched the product that was generated by the Virtual Organization on their own. “(Scholz 1994)

- **Walden Paddlers**

“One example for such a linkage of core competencies to a Virtual Organization is the company Walden Paddlers, founded by Paul Farrow. With the clear vision before his eyes, to produce and market high quality but low-priced kayaks made of recycled synthetic materials, he created a network of designers, suppliers, producers, and vendors, in short an unique know how pool, within half a year. Besides advantageous market conditions, Farrow lists the unconventional and flexible connection between the partners as a key factor for the fast success of his company, whose only employee is he. Therefore, in his opinion, the actual value of the company doesn’t rely on mere business property listed on balance-sheets, but on the network, built on the core competencies of the partners. “(Scholz 12/94)

- **Virtual Factory Euregio Bodensee**

Already in 1995, eight companies partnered up in the pilot project Virtual factory Euregio Bodensee. Today, this network includes 37 companies with a total of ca. 3000 employees. The most important task in the network is to produce new business relations. Collaboration’s rules are established, a standard contract for the foundation of virtual factories is agreed on, and a common infrastructure is drafted. Objective of the factory is the cost reduction through additional businesses that lead to higher capacity utilization. Through the installation of an intranet-infrastructure, all involved companies have full access to the project data, and now, they can search for suitable collaboration partners. By bundling the core competencies, the virtual factory achieves the development of new markets, with lower initial efforts. Also, it is a safeguarding of the location (Zmija 2002, Camarinha-Matos 2005, p.203). All this makes the Virtual Factory Euregio Bodensee an example for the concept of a Breeding Environment. The one-time initiation effort to build up a common infrastructure and to agree on the collaboration’s rules benefits a rapid configuration of the collaboration in the event of an order.
In the year 2002, a great number of Hungarian companies of the clothing and textile industry syndicated in order to coordinate their market activities. They founded the Hungarian Fashion Cluster as a reaction to the decline of prices in the clothing industry, due to cheap products of low quality from the Far East. The producers, designer, and service providers of different areas of the cluster are supported by institutions like research institutes, regional development associations, and industrial federations. The objectives of the cluster are:

- Trustful collaboration of the partners with the goal to offer products with superior quality
- Achievement of common efficiency through deliberate trust-building between the partners
- Mutual help through resources bundling, transparent information policies, and common market development.

(Camarinha-Matos 2005, p. 204f)

- Pannon Automotive Cluster

The Pannon Automotive Cluster was founded in 2000 as a consortium of subcontractors to the automotive industry in the region Pannon, western Hungary. Because of nearby production sites, such as Opel, Suzuki, and Audi, many small- and medium-sized companies settled in this region. They wanted to be able to deliver fast and flexibly, but they soon became aware of the fact that the competition between each other harmed their individual business success. As they sensed the chance for contracts could be improved by collaboration, the companies syndicated with the objective of appearing as a big system integrator before the producers and therewith improving the bargaining position of the individual suppliers through a comprehensive, configurable offer of competencies. Mutual support in investment projects, common marketing of the region to attract new producers as well as competitiveness are some of the designated fields of actions for involved partners. (Camarinha-Matos 2005, p. 206).

The first three examples demonstrate that approaches to order-specific collaborations were already industrial practice in the nineties. They should be understood as reactions to rising turbulence of outlet markets. In literature, the first explanatory approaches to becoming collaborations in general arose in the eighties, and they were based on the theory of core competencies (see Prahalad, Hamal 1990, p.17ff), and the transaction cost theory (see Williamson 1985). The last three examples show current tendencies in Virtual Organization building that are due to the implementation of a Virtual Breeding Environment. Figure 6 classifies introduced industrial examples in the cross matrix (compare figure 3).
Figure 6: Classification of industrial examples in the cross matrix

It is recognizable that the stability of these realization examples tends to be dynamic. At the same time, a fixed portfolio of possible business partners, from that a concrete consortium is instanced for a certain time, forms the basis for these collaborations. This instantiation can be carried out product-specifically with a long planning horizon (Lewis Galoob Toys, TelePad, Walden Paddlers), or order-specifically with a short planning horizon (Virtual Factory Euregio Bodensee, Hungarian Cluster, Pannon Automotive Cluster). The form of control of stated examples varies:

In the case of **Lewis Galoob Toys**, a constant Lead-Partner searches subcontractors and suppliers for the products to be marketed and then configures the usually hierarchical collaboration as dominant partner. The second case study, the **TelePad Corp.**, takes a similar course. Again, a constant Lead-Partner, who acts as the gateway to the key customers, compiles the competencies of his collaboration partners for the production of goods and services (here: a special computer) according to his requirements. **Walden Paddlers** as a sole trader business chooses a power structure without domination of one partner, so that the individual collaboration partners can participate longer in the development and production. Nevertheless, the instantiation of the Virtual Organization, and the selection and integration of suitable consortium partners is carried out on the basis of the requirements of Walden Paddlers.

The **Virtual Factory Euregio Bodensee**, the **Hungarian Fashion Cluster**, and the **Pannon Automotive Cluster** are manifestations of Virtual Organizations, with the
establishment of a Virtual Breeding Environment as a principle of collaboration. The collaboration preparation of collaboration-willing companies through corresponding agreements and rules forms the basis for a rather heterarchical collaboration, in which all members of the Virtual Breeding Environment equally tender for a contract. If a company gets the tender, it assumes the lead-function for the duration of the contract and configures the consortium.

To put it all in a nutshell, in the introduced examples, two manifestations of Virtual Organizations can be discriminated as tendencies.

The examples 1-3 are marked by hierarchies and lesser dynamic in configuration. The examples have their roots in Strategic Networks, in which a leading company collaborates with a fixed core of strategic partners. This fixed core is then supplemented order-specifically and dynamically by external partners. Examples 4-6 are obliviousy dynamic collaborations. The partnerships are marked by equality of partners. In some cases, hierarchies exist as a consequence of procured contracts. In this case, the company that has direct customer contact assumes the responsibility of searching and selecting the consortium partners. In their development, the last three examples derive from Project Networks that are best characterized by dynamic configuration of partnerships.
3 Performance Measurement as Approach to the Evaluation of Virtual Organizations

In the course of collaboration formation in Virtual Organization, the knowledge and evaluation of available alternatives in partner selection is an important task for the Lead-Partner. Only if the participation of the best suited business partners can be assured, an ideal fulfillment of the customer’s requirements can be provided. Due to the temporary limitation of the collaboration, there is almost no possibility to make iterative adaptations of the consortium or to plan long-term optimizations during the Operation Phase. To ensure the permanent bargaining and delivery capacity of the Virtual Organization, also possible fallback positions must be known early for the partner selection. It is the only way, to control the risk of the shortfall of a key partner and to integrate an alternative partner in the consortium at short notice. Especially in short-term collaborations, the ability to evaluate and compare the planned collaboration is crucial.

In the course of this chapter, firstly, basic approaches to the evaluation of company collaboration are introduced in section 3.1. Here, Performance Measurement, the Simulation, and Expert Systems are focus on.

Section 3.2 introduces the fundamentals of Performance Measurement. After an introducing motivation for the selection of Performance Measurement in the scope of this work, definitions and task definitions are established. Afterwards, available approaches to Performance Measurement are typologized, and possibilities of their IT-realization are presented.

Section 3.3 identifies the requirements for Performance Measurement of Virtual Organizations. For this, the necessity of prospective orientation is initially explained. Subsequently, criteria for the selection of a Performance Measurement approach are defined and requirements for the IT-realization in Virtual Organizations are discussed.

In the following section, available Performance Measurement concepts for Virtual Organizations are checked for applicability. Hereunto, the approaches introduced in section 3.2.2 are evaluated with the criteria established in section 3.3.2, leading to the selection of the SCOR-Model. Following the selection, the SCOR-Model is introduced as adequate approach to the evaluation of cross company process chains. Also, papers on its application in company networks are discussed. Undernehmensnetzwerken diskutiert. Finally, an evaluation of the IT-Systems for Performance Measurement introduced in section 3.2.3 is made on basis of the requirements for their application in Virtual Organizations described in section 3.3.3.
3.1 Existing Approaches to the Evaluation of Company Collaborations

For the methodic evaluation and improvement of company collaboration, there is a great number of different manual or computer-based tools in industrial practice today. In this section, the basic approaches in the described context and their function principles are presented. Doing this, the procedure of the evaluation and improvement can be divided independently from the used approach into three phases. Figure 7 shows available approaches on the vertical axis and bears mentioned specific phases on the horizontal axis.

Figure 7: Phases and approaches of the evaluation and improvement of company collaborations

Matter of the first phase is the **formal description of the collaboration**. This description can either be made place **directly** through modeling the structure or the attributes of collaboration, or it can be made **indirectly** through the formulation of factual knowledge about the collaboration. Models either statically describe the structure of the collaboration (i.e. through modeling the process chains and involved partners), or they dynamically describe specific attributes of the collaboration by means of dependencies or rules (i.e. the effect of inventory size on delivery times and production costs; see sections 3.1.1 and 3.1.2 for more information). This dependencies and rules are often described by mathematical relationships.
In contrast, factual knowledge usually formulates insights about the analysis-relevant aspects of collaboration verbally in form of generic knowledge or case-specific knowledge. From this knowledge, a basis for decision-making can be derived later (see section 3.1.3).

Subject of the second phase is the analysis of collaboration. On basis of the formal description of collaboration elaborated in the first phase, the actual analysis approach to evaluation of collaboration is applied now. Scores of methods and IT-systems are used for this in industrial practice and research. Here, three categorically different approaches can be told apart, just as shown on the vertical axis in figure 7. It is about Performance Measurement, Simulation and Expert Systems. Their mechanism of action is enlarged upon in sections 3.1.1 - 3.1.3.

After the analysis, the improvement of the collaboration is put into execution in the phase optimization of collaboration. For this purpose, simulation approaches and Expert Systems allot specific methods or algorithms. The model of collaboration serves as basis for the optimization approach of the Simulation. For its predefined initial values in form of experimental parameters, the values that theoretically lead to an optimal result according to the targets of collaboration are to be searched methodically in the course of the optimization. Expert Systems provide the basis for decision-making on footing of factual knowledge, just like they do for the analysis. Performance Measurement approaches are pure analysis instruments and don’t cover measures for the implementation. In this context, the weak-point analysis is used, so as to derive an improvement necessity and an improvement plan and realize measures of implementation. In the following sections, the three categorically different approaches to evaluation and improvement of company collaboration are given special attention.

### 3.1.1 Performance Measurement

Performance Measurement is a commonly used management instrument and is based on the conversion of real, usually high-complex business processes into a simplified process model. Key figures are defined and assigned to the defined processes by means of the process model that pictures the structure of collaboration. These key performance indicators represent the performance of respective processes. The term key performance indicator (KPI) isn’t used uniformly in English literature (compare Siegwart 1998, p.5). Following terms are also used in literature: Indicator, key number, key figure, metric, and ratio. (Meyer 1994, p.7) Within the framework of this thesis, the term key performance indicator and its abbreviation KPI are used. Bürkeler defined a KPI as operation-relevant, numeric information (Bürkeler, 1977, p.6). Through the determination of key figures, the performance becomes a quantifiable, scalable figure that produces comparable values, measured over time. An example for a KPI is the Perfect Order Fulfillment (P.O.F., in %), definable as the percentage share of the contracts, that were carried
out punctually (SCOR 8.0). These key figures can be quantified by a simple mathematical relationship:

\[
P.O.F.: \frac{\text{Number of contracts carried out punctually in a period}}{\text{Numbers of all contracts in a period}} \times 100\%
\]

With this model, information about the real processes can finally be derived from the collection, evaluation, and interpretation of the KPIs. They are usually documented in a performance report (compare to figure 8). The collection of the KPIs happens during the Operation Phase of collaboration, and they shed light on the performance made in the very moment of the data collection. Performance Measurement doesn’t contain explicit methods of collaboration improvement, because of its nature as pure analysis tool. Still, the performance report serves as the foundation for the identification of improvement potentials as well as for the planning and realization of concrete implementations. The effect of these implementations can be quantified afterwards by the change in the KPI values. This way, Performance Measurement can be used for the control of continuous improvement processes.
Performance Measurement as Approach to the Evaluation of Virtual Organizations

Performance Measurement is used for the retrospective evaluation of business processes in order to eliminate performance deficits detected ex post, and it mainly fulfills a feedback function for conducted activities (Andersen 2002, p.17). Thus, the value of a Performance Measurement particularly depends on the actuality of the utilized data and on the ability to implement measures of improvement. Figure 9 combines these two influences.

In the moment of the Performance Measurement, a past period is evaluated by means of available KPIs. In this book, the time span between the evaluated period and the calculation of the KPIs is called feedback time. After the KPIs are calculated and a performance deficit is detected, measures of improvement must be defined, planned and implemented as consequence. The time span between detection and elimination of the performance deficit is called implementation time within this book. Again, the feedback time and the implementation time sum up to the reaction time. In the figurative sense, the reaction time describes the space of time be-

Figure 8: Basic mode of operation of Performance Measurement for the evaluation and improvement of business collaborations

Figure 9: Composition of the reaction time running a Performance Measurement
tween the moments the fault is made until the fault is corrected. On the background of continuous process improvements as a typical application area of Performance Measurement, short reaction times are necessary in order to eliminate all measured but unwanted effects quickly.

### 3.1.2 Simulation

In general, simulations are experimental procedures, in that certain attributes of a really existing system are analyzed in a model of the original system. Based on the defined initial state, time-depended changes in state are studied. Object of the simulation is to gain knowledge about the final state and all transition states that lead to the final state, and transfer this knowledge to the real system. This way, also, models of non-existent collaborations in the sense of scenario evaluations can be worked out in order to estimate the properties of the collaborations before their actual establishment. Witte et al. understand simulations as the mapping of a complex system through a substitution system (model) and as the experiments made with this model (Witte et al. 1994, p. 17). The VDI-guideline (VDI is the association of German engineers) VDI3633 determines following definition for Simulations:

*Simulation is to be understood as the reproduction of a dynamic process in form of a model in order to gain knowledge that can be applied to the reality.*

Basically, one can distinguish between continuous Simulation and discrete Simulation (see figure 10). In continuous Simulation approaches, the changes in state of the model are permanently mapped, thus, with a continuous time flow. The modeling is conducted with differential equations. Discrete Simulation approaches appraise the changes in state in time-discrete (or time-driven) or event-discrete (or event-driven) points in time. Changes in state are caused by internal or external events like the initiation of an order or the arrival of a delivery. The Simulation of business collaborations is usually conducted event-driven or time-driven; this is why the following focuses on discrete Simulations.
Models that serve the formal description of collaborations can be divided into static and dynamic models. Static models map the structure of collaboration, for example, through displaying a process chain and involved partners. In turn, dynamic models map the time-dependency of the state of the model and characterize specific attributes of the collaboration that are relevant for the Simulation, for example, available resources, capacities and their current utilization as well as their need for orders. These process factors can either be described continuously or discrete. As an analogy to these different model types, an example from mechanics can be consulted. In mechanics, the discipline statics describes the geometry and the loading condition of a component, while the strength of materials appraises the behavior of the loaded component, bearing in mind the material properties. Unlike modeling business collaboration, this example is about a continuous model that can be solved analytically or numerically through a differential equation. Figure 11 shows the modeling of business collaboration within the first phase as a two-stage procedure. Initially, the structure of the collaboration is mapped (network structure), then, in the second stage, it is complemented by parameters and rules that describe analysis-relevant attributes.
The analysis phase covers the planning and the realization of simulation experiments with the model. A simulation experiment covers one or several simulation runs and is conducted through the discrete Simulation of the changes in state. The initial state of the system to be simulated may be predetermined or random. Usually, the Simulation is carried out decoupled, that means regardless of the real-time, for instance in form of a time-lapse Simulation. The quality of the analysis outcome depends strongly on the degree of realism of the system’s behavior. Because of this, the modeling is the crucial phase of the Simulation and requires a high degree of experiences and expert expertise.

Today, the optimization is no normal element of the Simulation, but rather is an exception among simulation tools. First approaches for the optimization of business collaborations through Simulations were developed within the scope of the European joint project ONE (Optimization methodologies for Networked Enterprises, GRD1-2000-25710). Object of the optimization phase is the identification of the ideal state of a system. For this, a solution space is defined that describes the combination of all possible system states. In this, it is commonly distinguished between two different approaches. Used categories are firstly approaches with optimization algorithms (deterministic or non-deterministic procedures), and secondly approaches without optimization algorithms (emulators).

Optimization algorithms on basis of deterministic procedures define so-called target vectors within the solution space and track down a local optimum. The application of non-deterministic procedures, for example on basis of genetic algorithms that thoroughly investigate the solution space is more extensive then the application of deterministic methods. Emulations only simulate the system behavior. Here, the optimization must be carried out manually through the variation of variables. The quality of the optimization depends greatly on the expertise and the skills of the operator.
3.1.3 Expert Systeme

Expert systems as a branch of artificial intelligence are classified as practical informatics. Artificial intelligence is the ability of computers to deal with tasks, that cannot be executed directly by manageable algorithms, and that usually demand human reasoning, and thus require intelligence (Engesser 1993). Expert systems are understood as program systems, that collect and save factual knowledge about a certain area from qualified specialists, and that can draw conclusions on basis of the collected knowledge in form of solutions to concrete problems. In general, two different systems can be listed. There are systems that evaluate the validity of a hypothesis, so their acts are either implications or deductions, and there are state-changing systems, that are not limited to mere suggestions but include acts. Discrimination takes place between deduction and reaction systems (Winston 1993).

In the context of the evaluation and optimization of business collaborations, deductive Expert Systems are common practice, so, following explanations refer to it.

Figure 12 abstracts the mode of operation of an Expert System for the evaluation and optimization of business collaboration. Base for the analysis and optimization is the formal description of the collaboration through factual knowledge. The factual knowledge can be formulated generically, that is independent from the actual application, or case-dependently, thus, formulated for the solution of an actual problem. One example for the formulation of factual knowledge is the supplier checklist that measures each supplier’s fulfillment of requirements regarding quality, costs, flexibility, etc., with a grading system. According to this application case, a question must be determined for the realization of the analysis in the analysis phase. The question serves the purpose of translating saved factual knowledge into a problem-specific basis for decision-making. Then, the deduction mechanism checks a formulated hypothesis for its validity with the basis for decision-making, which finally is the analysis of the described business collaboration. The basis for decision-making needed in the optimization phase is derived likewise, and serves the deduction mechanism for the evaluation of system states, bearing the optimization of collaboration in mind.
There are three different types of bases for decision-making in Expert Systems that is why they are used for the classification of Expert Systems in general, just as shown in figure 13:

- **Case-based systems** conduct their analysis with a so-called case-database. This case-database contains concretely formulated problems including their problem solution and serves with its data as a foundation for the basis of decision-making. In the course of the analysis, the Expert System tries to identify the most comparable case for the actual problem to be analyzed, and then to adopt given solution to the problem.

- The factual knowledge of **rule based systems** is stored in logical knowledge representation in form of facts and rules. Rules consist of an action and a triggering precondition that again is the combination of several facts. As a general example is the rule “If A and B, then C”. A and B correspond to the facts of the precondition, C to the action. The rules for the organization of the basis for decision-making must normally be directly formulated by experts and entered and maintained in the system.

- The third class describes systems that carry out learning processes independently through decision trees. Decision trees or tables are usually used for classification problems. For the formulation of the basis for decision-making, a quantity of examples to be classified is described with their respective attributes and concrete manifestations. During the processing, the system runs down a path, the so-called
search tree. In it, the defined attributes emerge as nodes in the search tree and their possible manifestation are represented by the node’s edges. Running down the search tree path, the system always chooses that edge of a node that corresponds with the example at hand, and finally arrives at the final node (leave). This final node determines the action (or, in case of a classification problem, the class), that can be derived from the example at hand.

3.2 Principles of Performance Measurement

The application of Performance Measurement for the evaluation of business processes in manufactures has been deployed for many years, and it has come along with the development of conceptual approaches. At the same time, there are many IT-systems on the market that support the implementation of Performance Measurement. An advantage of Performance Measurement over other approaches is that nearly all data needed for the evaluation of the key performance indicators can be provided through operating data that is recorded by the companies anyway. For example, to calculate the Perfect Order Fulfillment introduced in section 3.1.1, only the total number of orders within a fixed period (i.e. last month) and the total number of orders completed in due time within the determined period are required. Also, the calculation of all key performance indicators can easily be automated, if the data and a mathematical formula is at hand. As a consequence, Performance Measurement causes comparatively little additional expenditures through extra data or special abilities of the user. On the other hand, approaches such as Simulations or Expert Systems require far more expertise and IT-infrastructure. This is why they are rarely used in little businesses without an own IT- or development branch. The practical examples of Virtual Organizations introduced in section 2.4 make a clear statement that, in many cases, small or medium-sized businesses decide to collaborate in order to offer comprehensive solutions (i.e. Pannon Automotive Clusters). So, first of all, Instruments for the support of collaboration formation should economically applicable in small and medium-sized businesses. For this reasons, the Performance Measurement approach is further elaborated in this thesis.

After the presentation of the preliminary definitions (3.2.1), the following sections give an overview and classification of currently available conceptual approaches to Performance Measurement for the evaluation of business processes (3.3.2). Finally, different alternatives of the IT-support of the Performance Measurement are described (3.3.3).
3.2.1 Origin and Definition

Science and industry have concerned themselves with the designing of Performance Measurement for the evaluation of entrepreneurial performances for many years already. Originally utilized as an operational analysis instrument, Performance Measurement only focused on matters of expenses for a long time. The evaluation of business processes (that range from production processes over logistic processes to service processes) and their comparison within the scope of process-benchmarks is a typical area of application for Performance Measurement today. Since the mid-nineties, also approaches to cross-company evaluation of stable supply chains are known.

In order to define Performance Measurement, the paragraphs below enlarge on the origin and development of the term performance. From this, a preliminary definition is derived that forms the base for the preliminary definition of Performance Measurement.

- Performance

The term performance dates from the 15th century. Andersen and Fagerhaug describe the original meaning of the word with the description “… performance is believed to have originated in the fifteenth century, and then in the meaning of a play or exhibition of some sorts.” (Andersen and Fagerhaug 2002, p.3). Still today, performance is described in dictionaries as “a particular entertainment presentation before an audience” and as a “way of working or functioning” in. Hence, the natural and partly still valid significance of the term falls outside of the subject area that is industrial engineering. Some synonyms for performance in the context of the business administration are: accomplishment, efficiency, capability and satisfaction (Wettenstein 2002, p.15).

The usage of the term performance in industrial engineering for the characterization of industrial processes traces back to the industrialization in the 19th century and has lead to a wide range of different definitions, mainly because of its origin outside of the subject area. Definitions always depend on their application context: In the first half of the 19th century, English manufactures aimed at producing as accurate as possible. Therefore, quality was a crucial criterion for the description of performance. Towards the end of the 19th century, and in times of the incipient Taylorism, the supervision of the employee productivity gained in importance and became the central evaluation criterion. Important key performance indicators for the description of the performance in this time were the degree of capacity utilization and labor efficiency. In the eighties, when former producer markets became consumer markets, this commonly accepted definition of performance as the ratio between input and output was replenished with additional elements (Andersen, Fagerhaug 2002, p.11). For instance, to-
day, also factors like environmental pollution of a process play an increasingly important part in the definition of performance.

The significance of the term performance has grown more complex over the years. The dominating terms in the definitions of performance are *efficiency* (ration between input and output) and *effectiveness* (efficacy, capability). Rolstadas complemented them by the perspectives quality, productivity, quality of work life, innovation, and profitability/budget ability (Rolstadas 1998, p.989f) and therewith replenished the mere monetary perspective of the definition with social and technical perspectives. Generally, performance is understood as the degree of target achievement regarding predetermined criteria. It depends on the application, which criteria are consulted for the description of performance. As a consequence of these considerations, following preliminary definition of Performance results:

*Performance is the degree of target achievement of a process regarding predetermined and application-dependent criteria.*

- **Business Process Performance**

In literature, the performance of business processes is usually called business process performance in literature (Gladen 2002, p.5ff). Business processes are generally understood as the integrated, chronological arrangement of activities, procedures or workings that make an essential contribution to the value creation of a company (Seidl 2002, p.27). Every process should have a measurable input and output, should be repeatable, and fall into the area of responsibility of an executive.

The business process performance is usually appraised primarily on basis of the produced output, and therewith, it is judged by the result for the customer or the value creation for a company. Besides the evaluation of the output, also factors like factor application (viz. the input) or the time needed for the transformation are taken into account.

- **Performance Measurement**

English dictionaries describe the term Performance Measurement as the act or process of measuring. Here, measuring is understood as “to choose or control with cautious restraint”, “to regulate by a standard”, as well as “to estimate or appraise by a criterion”. Hence, measurement is defined as a process that covers the measuring, the analyzing, and the communication of a subject to evaluation (Wettstein 2002, p.18).

Correspondingly to this definition of the processes, Performance Measurement is understood as the acquisition of the performance, the analysis, and finally the
communication. Doing this, literature usually discriminates between the two phases data acquisition and data analysis. Altogether, following preliminary definition of Performance Measurements results:

Within the scope of this thesis, Performance Measurement is understood as the, measuring, analyzing and communication of the performance of business processes in industrial establishments.

The objective of Performance Measurement as an analysis instrument is to pinpoint improvement potentials of entrepreneurial action, and to establish the possibility of eliminating performance deficits in existing process chains. The application of a Performance Measurement does not depend on the current competitive position; in cut-throat competition, the elimination of a performance deficit can quickly become a question of survival, while the market leader must focus on the maintenance and strengthening of its competitive advantage (Straub 1997, p.42ff).

Performance Measurement is a tool for the strategic planning, and functions retroperspectively as measures of optimization for the future are derived from the evaluation of real processes after the event (analysis of the past). This is why Aichele (Aichele 1997, p.4) understands the usage of key performance indicators in Performance Measurements as a management tool that helps to realize following objectives of the strategic plane:

- Distinction of the important and unimportant in the complexity of business processes through aggregation of information from a mass of unsorted data.
- Detection of causal interrelations of entrepreneurial actions through transparency in cause and effect as well as in the interplay of positive and negative factors.
- Evaluation of one’s own position as a competitor on the market, identification of one’s strengths and weaknesses in comparison with other competitors, and the ability to timely react to innovations and changes of the market.

Literature suggests different procedure models for the concrete application of Performance Measurement (Böhnert 1999, p.91ff). Their basic components are summed up in figure 14:
In the first phase, the *modeling*, the appointment of the Performance Measurement Team, the determination and modeling of the processes to be examined (that is the collaboration's structure) as well as the determination of the key performance indicators for the quantitative evaluation of the processes to be investigated take place. In the *analysis phase*, all data needed for the calculation of the key performance indicators are collected in order to compute said thereafter. Finally, the results are evaluated and presented in form of performance reports. The performance reports are initial points for the planning of measures of improvement within the framework of organizational and technical process design. Because of this, some authors supplement the procedure-model phase *optimization* with the implementation (planning, realization and control) of the measures of improvement, and then speak of Performance Management.

Figure 14: Generic procedure model of Performance Measurement (compare to Straub 1997, p.59ff)
3.2.2 Available Approaches to Performance Measurement and their Typologies

The subject of Performance Measurement is the evaluation of a work result or a working process and, against the background of this, can either be product-oriented or activities-oriented. A very common term for product evaluation in literature is product benchmarking, but it is not further elaborated within the scope of this thesis. First of all, the initiation of Virtual Organizations bases on the consortium partner's ability to integrate all involved business processes quickly. For this reason, a Performance Measurement for the support of collaboration formation must primarily deal with the evaluation of all involved processes, and thus have an activities-oriented nature. Today, the main cause for the initiation of Performance Measurement in companies is pricing pressure on the market. Concrete projects aim at matters of expense or resources as well as the supervision of the compliance with instituted guidelines and policies, just as usually done in quality management.

As shown in figure 15, Seidl divides the conceptual approaches to activities-oriented Performance Measurement available today into three groups.

![Figure 15: Typology of the approaches to Performance Measurement](image)

Seidl discriminates between process-oriented approaches, quality-oriented approaches, and cost-oriented approaches. Some concepts can't be classified clearly, but rather include features of several approaches. Still, all approaches have a dominant classification criterion, that makes a attribution to one of the approaches possible. In this case, performance evaluation is usually carried out with so-called performance-perspectives. These perspectives differ in their respective concept. Frequently used perspectives are expenses (profitability, efficiency), effectiveness, quality, and flexibility. In this section, characteristics of all individual approaches are described, and exemplified by concrete concepts.
Process-oriented Approaches

Since the introduction of Business Process Reengineering (BPR) by Hammer and Champy in the year 1994, in general, a stronger process-orientation is observable in business management (Seidl 2002, p.27). While it forces the radical modification of processes, other methods, like the Continuous Process Improvement (CPI), aim at the evolutionary advancement of existing processes. In this context, the Performance Measurement serves the planning and monitoring of measures of improvements through the quantification of the process performance. Single aspects in evaluation of a process can correspond to several characteristics of the process, for example, the strategy perused, procedures and work routine, the expertise and utilization of labor, and employed technologies and systems (Seidl 2002, p.28). If continuously or periodically realized, Performance Measurement results give information about chronological changes in the performance of a process as well as its current value. The developments that can be read off these time series are the basis for the identification of improvement potentials and the design of a CPI-project. Nevertheless, the continuous improvement of processes through the capturing of time series has the stability of processes as a precondition. Only in the case of comparability of the periodically captured Performance, measures of improvement can be derived and checked for their effects.

Process-orientated Performance Measurement can either be carried out within an organization (intra-organizational), for example, for the evaluation for a single process, or it can include several organizations (inter-organizational), like for the evaluation of a chain of processes. Today, a multitude of concepts for both intra- and inter-organizational process-orientated Performance Measurement is available. The best known representatives are the SCOR-model of Supply Chain Council and the Balanced Scorecard approach of Kaplan/Norton.

In 1996, the Supply Chain Operations Reference model (SCOR-model) of the Supply Chain Council was introduced as an inter-branch standard and diagnoses instrument for supply chain management. Objective of the application of the SCOR-model is the modeling, analysis, and improvement of inter-organizational process chains in the operation phase of a stable supply chain. The SCOR-model is the today’s most developed approach to the modeling and evaluation of inter-organizational process chains and can be called a quasi-standard, because implementations are found all around the world. Planned for the enhancement of the SCOR-model, there are also some reference models for development processes (DCOR- Design Chain Operations Reference model, since 2004) or complete value chains allowing for service processes (VCOR-Value Chain Operations Reference Model, since 2003) under way. However, they are still at an early stage of development.
The **Balanced Scorecard** approach (BSC) is a managerial concept that enables a company to continuously control the intra-firm operative realization of the corporate strategy. KPIs serve as base for this managerial concept. But in contrast to classic KPI-systems that are mainly monetary-oriented, the BSC-approach also takes non-monetary performance-perspectives into account, such like customer satisfaction, process improvement, and personnel development. With the BSC-approach, both qualitative and quantitative target values can be captured together in one system (Eberth 2001, p.3).

- **Quality-Oriented Approaches**

Within the scope of quality management, an essential activity is the examination of the process quality. On this background, the tendency to process-oriented alignment of quality management is to be understood. Likewise, a stronger process-orientation is noticeable in the advanced ISO-9000-2000ff series of standards. The new standard obligates companies to define processes, describe their sequence and interrelations, to observe and analyze processes, and, finally, to initiate measures for their continuous improvement. Basis of process evaluation within the framework of quality management is often the identification of the influencing variables of the processes in order to detect and eliminate all disturbance variables. In this context, an example for such a method is the **Six Sigma Method**, a zero-defect concept that strongly bases on statistical methods and that provides a construction kit of methods. In quality-oriented approaches, Performance Measurement focuses mainly on the product and its evaluation. The process is understood as a controlled system with disturbance and correcting variables as to influence the work result product. Another widespread quality-oriented approach is the **EFQM-model** (European Foundation for Quality Management), which was developed as a so-called diagnose instrument for quality management (Hieber 2002, p. 93f). Here, the criteria customer- and employee-satisfaction are in the foreground. The model discriminates between enabler-criteria that describe the activities of an organization and result-criteria that describe the results reached by the activities. The model serves the purpose of target description of an organization and the quantitative capturing of the percentage share of targets achieved.

- **Cost-Oriented Approaches**

Cost-oriented approaches have their focus on the cost-oriented control and optimization of business processes. In doing so, the Performance Measurement bases primarily on monetary KPIs and is strongly influenced by business-management. An example for a cost-oriented approach that understands and evaluates entrepreneurial procedures as processes is the **Activity-Based-Costing (ABC)**. ABC is understood as the process-oriented direct capturing and measurement of costs within the plane of their origin that is the plane of operational activities or processes.
The evaluation of the processes is done on basis of the so-called performance consumption, which is a cause-oriented cost allocation. ABC analyzes the direct production costs on all planes of the production process, that’s why it’s also called process-cost-calculation. Judged from the cost-perspective, the estimation of process costs is an effective support for the optimization of the core processes of any company. Supplementarily, the **VDI Guideline 2520** should be mentioned at this point, because it provides practice-oriented KPIs for the evaluation of logistic Processes in SMEs. The guideline comes with nine so-called basis-indicators that mainly capture logistic costs besides the aspects efficiency of logistics, order lead time, and stock turnover.

### 3.2.3 IT-Support of Performance Measurement

The realization of Performance Measurement for the evaluation of business process is always connected with the collection and handling of a big data volume, from which the KPIs must be computed with mathematical operations. In particular the user-friendly archiving, editing, and display of the big data volume is of great importance for the analysis possibilities. That is why, today, many IT-systems are available on the market, each one supporting different phases within the Performance Measurement procedure (compare to figure 14).

The IT-solutions for the support of Performance Measurement used in industrial practice range from simple excel-applications to sophisticated analysis-tools that are integrated in production planning and control systems (ERP-systems). For the classification of the IT-solutions for Performance Measurement, the concept of the spectrum of supported functionalities can be consulted. Applying said concept, Wettstein differentiates between 5 categories (Wettenstein 2002, p.307):

- Solutions that cover a broad spectrum of Performance Measurement functionalities
- Solutions that mainly support the visual communication of Performance Measurement
- Solutions that mainly support the analysis of data
- Solutions that support the data collection and data management
- Solutions that are coupled with ERP-systems
Referring to the procedure of a Performance Measurement, the different solutions support the single phases with varying priorities. Figure 16 creates relations between the phases of Performance Measurement and the 5 categories introduced. The declining coloration level of the bars indicates that the functionalities of the IT-systems can’t be positively assigned to one single category.

![Phases of Performance Measurement](image)

It is clearly observable that all available IT-systems have different origins and, as a consequence of the first, follow different approaches: On one hand, solutions that base on the application of a special conceptual approach (like SCOR or BSC) are offered. Examples are the products ADOLog and Simpel. Other solutions are modules or stand-alone applications as enhancements to ERP-systems. They base on the integration and usage of ERP databases for the calculation of the KPIs. Examples for this princip are the products SAP.APO/BW and the ARIS Process Performance Manager (ARIS PPM). Finally, there are also some generic data management systems available on the market. They are mostly used for data collection and data management, because of their comprehensive analysis and visualization possibilities. Actually, they are no specific Performance Measurement systems in the true sense of it, but they are listed for the sake of completeness. Examples are the products PS-Explore and Matlab. Figure 17 shows an array of frequently used IT-systems for the process-oriented Performance Measurement and their classification.
of Wettenstein. IT-systems, that exclusively focus on cost- or quality oriented aspects, shan’t be further examined in this context. It remains to add that the classification shown in figure 17 can be done unambiguously, because many systems bear aspects of more then one category. For instance, today, many products offer data interfaces for the data import from ERP-systems. Doing the classification, only the product’s application emphasis was taken into consideration.

Figure 17: Examples of process-oriented IT-systems for Performance Measurement and their classification by Wettstein

Relating to the application of IT-based Performance Measurement systems in industrial practice, a survey (Wettstein 2002, p.100ff) proves that 75% of all companies have used IT-systems for the Performance Measurement until the year 2002, at the same time, a 100% of the companies with more then 10,000 employees have enacted IT-systems. Two third used standard software, one third used own products. After Wettstein, products of Cognos and SAP are the most common ones. Günther and Grüning quantify the share of SAP-users with 37% (Günther, Grüning 2000).
3.3 Requirements on a Performance Measurement for Virtual Organizations

Within the scope of this section, the necessity of a prospective alignment of Performance Measurement is concluded from the characteristics of Virtual Organizations (3.3.1). Subsequently, in section 3.3.2, the criteria needed for the evaluation and the selection of a Performance Measurement approach (introduced in section 3.2.2) for Virtual Organizations are established. The last section within this section outlines the requirements on the IT-support of Performance Measurement in Virtual Organizations.

3.3.1 Necessity of the Prospective Evaluation of Virtual Organizations through Performance Measurement

Dynamism in collaboration through order-related configuration of the consortium was described to be the central characteristic of Virtual Organizations. Changing partnerships and process chains lead to shortened operation phases and shift important planning decisions to the initiation phase.

Figure 18: Life cycle of Virtual Organizations in comparison with stable collaborations
The Performance Measurement has been introduced as an analysis instrument for the detection and elimination of deficits in business processes through retrospective evaluation. Nevertheless, an important precondition for the application is the stability of the determining factors in terms of stable process chains and partnerships. Then, if short reaction times of the Performance Measurement are given, the detected performance deficit can be eliminated promptly. Executing the Performance Measurement in stable collaborations (for example in strategic alliances or joint-ventures), all stated requirements on the stability of partnerships are met. Conceptual approaches like the SCOR-model take advantage of the stability of the determining factors in order to evaluate retrospectively and continuously improve involved processes during the long operation phase (see top of figure 18). In this case, the effectiveness of Performance Measurement mainly depends on the reaction time, and therefore the ability to react quickly to measured symptoms. The current efforts to reduce these reaction times can be divided into two groups with different approaches.

- Reduction of the Feedback Time

Figure 19 shows the influence of the feedback time over the reaction time in Performance Measurement.

![Figure 19: Shortning of the reaction time through reduced feedback time](image)

The length of the feedback time is essentially marked by three influences: firstly, the actuality of the data used for the computation of the KPIs, secondly, the expenditure of time for data collection and KPI computation, and thirdly, the visualization and analysis of the KPIs. Taking this into account, the feedback time is mainly characterized by activities during the modeling and analysis phase of Performance Measurement (compare to figure 14).
Surveys of benchmarking projects from the 90s found out that the data collection of inter-organizational processes usually need the biggest time slice (often up to 45%). At the same time, the problem of availability of up-to-date data is frequently discussed in practical guides about Performance Measurement in the 90s (Mertins 1995, p.26).

In consequence, a wide range of different approaches to the IT-support of Performance Measurement of Business processes have arisen over the last years (compare to section 3.2.3). Objective of the IT-systems developed in this context were mostly the acceleration and automating of the data collection, besides the support of the calculation and outcome presentation. At this, first and foremost, approaches that allow the permanent access to real time data through the integration into ERP-systems must be mentioned.

- Reduction of the Implementation Time

Figure 20 shows the influence of the implementation time over the reaction time of Performance Measurement.

The implementation time covers the planning, the realization, and the control of measures of improvement that can be derived from the results of Performance Measurement. Therefore, the implementation time is determined by the configuration of the implementation phase, and it is not a subject of Performance Measurement but of Performance Management, according to

Figure 20: Abbreviation of the reaction time through reduced implementation time
the preliminary definition. For this reason, this aspect is not further elaborated with the scope of this thesis. Measures for the abbreviation of the implementation time are mostly found in the disciplines work science and business organization. Keywords are Continuous Process Improvement (CPI) and Kaizen.

Because of their extremely short operation phase, Virtual Organizations render the continuous process improvement impossible. Therefore, described approaches for the reduction of the reaction time are quite useless in Virtual Organizations. In Virtual Organizations, the course for a high process performance is not set within the operation phase, but is primarily predetermined in the initiation phase when the actual collaboration formation takes place. Already the selection of the consortium partners and the knowledge of alternatives decide over the later capacity to act and achievable performance of the projected consortium. This is why for Virtual Organizations, the main questions are which consortium is the best qualified for the next contract and what alternatives of the partner selection are available as fallback positions.

Hence, the objective of Performance Measurement in Virtual Organization isn’t anymore the creation of powerful process chains in the long run, but now, it is the pre-collaboration identification of those potential partners that are able to contribute to process chains with high performance at once. From the entrepreneurial point of view, the ability of continuous improvement doesn’t any longer have the top priority. Now, on one hand, the ability of potential consortium partners to offer their own value creation contribution within a Virtual Breeding Environment for building up a Virtual Organization is crucial as well as the fast incorporation of this contribution into a new consortium. On the other hand is an important requirement on the Lead-Partner to identify the possible partnerships needed for the fulfillment of a contract in order to be capable of the instantiation of high performance consortia with bargaining and delivery capacity at short notice. From this follows, a Performance Measurement in Virtual Organizations may not be based on the capacity to react quickly to detected deficits. Figure 21 reveals why this conventional comprehension isn’t suitable for Virtual Organizations and describes the principle of prospective Performance Measurement.
Process improvements that are deduced from the retrospective evaluation of the operation phase can hardly be implemented timely in a Virtual Organization, because of its high dynamism. Therefore, Performance Measurement must aim at enabling the Lead-Partner to estimate the performance of a planned consortium yet in the initiation phase of the next contract, considering all available alternatives in partner selection. This is how the usually resulting reaction time can be overcome and transformed into an action time for collaboration formation (see bottom of figure 21). Now, potential weak-points in the process chain of a planned consortium can already be predicted and probably avoided in the initiation phase. The Performance Measurement apparently serves as decision support for the Lead-Partner within the scope of collaboration formation.
3.3.2 Criteria for the Selection of a Performance Measurement Approach

Basically, all concepts for Performance Measurement of industrial processes introduced in section 3.2.2 have different objectives and hence also different key aspects of development. So in order to be able to estimate to what extent a concept is suitable for the application in Virtual Organizations for the support of collaboration formation, one firstly has to determine all required attributes for a Performance Measurement. Until now, there is neither a systematical examination of the requirements on Performance Measurement for Virtual Organizations nor adequate selection criteria found in literature. Indeed, Hieber discussed the adequacy of different concepts for logistic networks and also stated criteria for their evaluation (Hieber 2002, p.95), but nevertheless, the criteria were no outcome of a systematical development. Anyway, the criteria can easily be deduced from the characteristics elaborated in section 2.2. For this reason, the required features of Performance Measurement for Virtual Organizations are described with following 5 criteria:

- **Network-Orientation**

  Trend towards the relativization of borders described in section 2.2 implies a great dynamism in the composition of the consortium and, due to the high scattering of value creation, requires an integration of all potential partners in one Performance Measurement. The utilized approach must therefore be appropriate for the description of inter-organizational process chains and for the inter-organizational capturing of KPIs.

- **Process-Orientation**

  The high resource-orientation as well as the trend towards the detemporization in Virtual Organizations (compare to section 2.2) demands a process-oriented perspective of the Performance Measurement that is the availability of an integrating process model. The analysis should also provide non-monetary perspectives in addition to the evaluation of monetary KPIs (compare to section 3.2.2).

- **Multi-Level Orientation**

  Virtual Organizations are function-oriented, because they are geared to concrete, usually individual demands of the customer and not to the service of anonymous mass markets (individualization, see section 2.2). The ability to integrate consortium contribution to powerful inter-organizational process chains at short notice is essential for the success of a Virtual Organization.

  An Analysis of the Performance should cover the operative level for the short-term control of the Virtual Organization, the tactical level for the mid-
term adoption of the provided resources and capacities, and the strategic level for the long-term planning of the available competencies. This is why an analysis of the processes with differing range is required in Virtual Organizations.

- **IT-Support**

  The delocalization as an attribute of Virtual Organizations on one hand and the need for a high integration level of the involved partners on the other hand (section 2.2) particularly require an integration of the information flows. Regarding the Performance Measurement, the central availability of a distributed database must be reassured. This requirement may be met through the usage of ICTs, in other words IT-based Performance Measurement systems. Hence, the availability of examples for the implementation of the different conceptual approaches in IT-systems a fundamental criterion for the evaluation of the different approaches.

- **Partnership-Oriented**

  The integration of the business processes in Virtual Organizations before the background of function-orientation demands the possibility to evaluate the consortium’s ability to collaborate. The Performance Measurement must therefore be inter-organizationally aligned and it also must take inter-organizational aspects into account.

### 3.3.3 Requirements on the IT-Support of the Performance Measurement in Virtual Organizations

Already in section 3.3.1, the Initiation phase (more detailed: the partner search and selection) was described as crucial for the success of a collaboration. Bearing this in mind, the **Support of collaboration formation** (and therewith strategic and tactical planning) is an important criterion for the suitability of IT-based Performance Measurement systems. At the top of figure 22, it shows the manifestations of this criterion: Minimum support is rendered by systems with simple process monitoring for the control of the business processes. Systems for the comparison of suppliers and systems with benchmarking functionalities offer advancements. In the ideal case, the IT-system also makes the identification and evaluation of all basically feasible consortium variants possible. An isolated comparison of the process performance of single consortium partners isn’t needed anymore, because the performance of the whole process chain of a consortium is judged.
Figure 22: Criteria for the selection of IT-based Performance Measurement systems for Virtual Organizations and their manifestations

The function-orientation of Virtual Organizations and the related high scattering degree of possible process chains required the organizational and technical integration of potential partners through the IT-system. At the bottom of figure 22, the manifestations of this criterion are summed up. Ideally, the integration of information flows in Virtual Organizations with qualified IT-systems is carried out under the participation of all members of the Virtual Breeding Environment (Linde 1997, p. 40ff). In this case, all potential consortium partners can capture and evaluate their own performance data through shared, decentral access. Solutions usually base on intranet solutions or web-based systems. Systems with a low degree of integration of the potential partner only capture the performance of single enterprises. An advancement is the additional capturing of performance of all partners that are really involved in a collaboration.
3.4 Appropriateness of available Performance Measurement approaches for Virtual Organizations

In section 3.2.2, approaches for the Performance Measurement were introduced and typologized with the classification of Seidl. The following now evaluates their applicability for Virtual Organizations on the basis of the criteria defined in section 3.3.2. Figure 23 summarized the applicability of presented approaches qualitatively.

![Table showing the applicability of different performance measurement approaches for Virtual Organizations]

<table>
<thead>
<tr>
<th></th>
<th>SCOR</th>
<th>Balanced Scorecard</th>
<th>Six Sigma</th>
<th>EFQM Model</th>
<th>Activity Based Costing</th>
<th>VDI 2520</th>
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<td>Network oriented</td>
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<td>-capturing all involved partners</td>
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<td>-describing the entire process chain</td>
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<td>Process oriented</td>
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<td>-not exclusively monetary acquisition</td>
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<td>-Utilization of an integrating process model</td>
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<td>Multi-level oriented</td>
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<td>-strategic, tactical und operative elements</td>
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<tr>
<td>IT-supported Performance Measurement</td>
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<td>-implemented in conventional IT-tools</td>
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<td>Partnership oriented</td>
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<td>-contains explicitly cooperative aspects</td>
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Figure 23: Applicability of approaches to Performance Measurement for Virtual Organizations

It can be learned from figure 23 that none of the surveyed conceptual approaches completely meets all criteria requirements of a Performance Measurement in Virtual Organizations. The SCOR-model provides the most comprehensive approach, but it has great deficits in the partnership-orientation. In this context, dissertation of Hieber should be mentioned (Hieber 2002: Supply Chain Management- A Collaborative Performance Measurement Approach), who took this deficit as a prompt to an advancement of the model (see Section 3.4.2). The SCOR-model’s strengths over competing approaches are definitely the process-orientation of the model as well as the network-orientation. Especially these two criteria are very weakly pronounced in the other approaches that place their emphasis on intra-organizational Performance Measurement. Globally dispersed consortia in Virtual Organizations.
also need a world-wide availability and accessibility of the Performance Measurement approaches in order to ensure the involvement of all potential consortium partners. Now, an inter-organizational Performance Measurement assumes common definitions of processes and calculation methods of the KPI’s. Without them, an inter-organizational comparison of the Performance is only possible to a limited extend and after the realization of certain correction procedures (Straub 1997, p.44). The SCOR-model can be viewed as quasi-standard for the modeling of process-chains and appears globally, because of the world-wide net of the Supply Chain Council.

For this reason, the SCOR-approach is taken as initial point for the method development of a Performance Measurement for Virtual Organizations within the scope of this thesis. Originally intended for the modeling of supply chains, it has to be checked for its applicability to the network structure and to the dynamism of Virtual Organizations. For this, the basic attributes of the SCOR-model for the evaluation of inter-organizational process-chains is described in section 3.4.1. Then, in section 3.4.2, existing approaches to application of the SCOR-model in the context of company networks are presentet. Finally, section 3.4.3 appraisals the applicability of available Performance Measurement systems for Virtual Organizations.

### 3.4.1 Attributes of the SCOR-Model as Concept for the Evaluation of Inter-Organizational Process Chains

The SCOR-model was developed for the modeling and evaluation of inter-organizational process chains in stable supply chains. It provides a three-leveled hierarchy for the display and decomposition of inter-corporation processes. The essential components of the SCOR-model are the five main processes of reference source, make, deliver, return and plan that altogether firstly serve for the modeling of the intern processes of a company. Through connection of the deliver-processes of a company with the source-processes of its customers, these processes can be compounded to inter-organizational process chains. SCOR discriminates between three product-related process categories in the decomposition:

- Processes of the category *engineer-to-order* refer to the creation of customized manufacturing to order, viz. the creation of uniques, usually investment goods
- Processes of the category *make-to-order* refer to the contract-oriented manufacturing of configurable individual goods
- Processes of the category *make-to-stock* refer to the contract-independent manufacturing of standard products, often consumer goods

Capital-intensive, complex investment goods (thus engineer-to-order) were already identified as the typical end products of Virtual Organizations in chapter 2. It must
be said that single product contribution to the end product can certainly be configurable individual goods (make-to-order) or standard products (make-to-stock).

The evaluation of the performance of the SCOR-processes is done with predefined KPIs that are assigned to each individual process on each of the three decomposition levels. Today, SCOR provides five performance-perspectives for the analysis of the processes; Reliability, responsiveness, flexibility are geared to customers, and the perspectives cost and assets focus on the intern processes of a company (Zeller 2003, p.19). Table 2 summarizes the five performance-perspectives of the SCOR-model and gives their definitions.

<table>
<thead>
<tr>
<th>SCOR-Performance-Perspektive</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>The performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>The speed at which a whole consortium or a single consortium partner provides products to the customer.</td>
</tr>
<tr>
<td>Flexibility</td>
<td>The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.</td>
</tr>
<tr>
<td>Cost</td>
<td>The costs associated with operating the supply chain.</td>
</tr>
<tr>
<td>Asset Management</td>
<td>The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.</td>
</tr>
</tbody>
</table>

Table 2: Definition of the SCOR-performance-perspectives (Supply Chain Council 2006, p.6)
For the visualization of the analysis outcome, the Supply Chain Council suggests so-called SCOR-cards. A SCOR-card sums up the Performance of a company within a supply chain from its own perspective and contrasts it with comparison values customary in this line of business for the purpose of benchmarking. Need for improvements and strategic mistakes in operations can be recognized from the DCOR-card. An example for such a SCOR-card is shown in figure 24.

<table>
<thead>
<tr>
<th>Performance Perspektiven</th>
<th>SCOR Level 1 Kennzahlen</th>
<th>Aktueller Wert</th>
<th>Median</th>
<th>Best-in-class</th>
<th>Defizit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kundenorientierte Perspektiven</strong></td>
<td>Reliability</td>
<td>Perfct Order Fulfilment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Responsivenss</td>
<td>Order fulfillment</td>
<td>Cycle time</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexibility</td>
<td>Upside Supply Chain Flexibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upside Supply chain Adapability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Downside Supply chain Adapability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intern ausgerichtete Perspektiven</strong></td>
<td>Cost</td>
<td>Cost of goods sold</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supply Chain Management Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assets</td>
<td>Return on Supply Chain Fixed Assets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cash-to-cash Cycle Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Return on Working Capital</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 24: Example of a SCOR-card
For each one of those KPIs captured in the SCOR-card (in the examples they are the level 1 KPIs of the SCOR-model), the current performance of a company is captured. **Median** and the **Best-in class** value are listed for each KPI as benchmarks. The Supply Chain Council places these benchmarks for different branches of trade at its member’s disposal. The Median, a term from statistics, is described as the value that divides a group into two equal parts. In sorting all available KPI-values captured in the benchmarking according to their greatness, the meridian is thusly the value that claims the middle position in this order. The best-in-class value corresponds to the best performance captured in the benchmarking. In the last column of the SCOR-card, the current performance-deficit is documented for every KPI. This deficit correlates to the percentage of deviation from the best-in-class value and describes the improvement potential.

### 3.4.2 Approaches for the Utilization of the SCOR-Model in Company-Networks

Although originally developed for the application in supply chains, there are also approaches for the utilization of the SCOR-model in company-networks. Efforts in this context mainly refer to stable networks and the application of the SCOR-model for the evaluation of the network within the operation phase. Examples for the implementation of SCOR in Virtual Organizations, which are dynamic networks as well as approaches for the application of a SCOR-based Performance Measurement in the initiation phase do not exist. Therefore, the Collaborative Research Center 559 (Modeling of Large Logistics Networks) discuses the experiences drawn from case-studies regarding the SCOR-modeling of processes that occur within company-networks (Hieber, Nienhaus 2002, p.5f). These case-studies originate from the research project ProdChain (IMS 99006, IST 2000-61205) and base on the application of the SCOR-model in three company-networks that are mainly discriminated by the stocking mode of their end products:

- **Network A**: Investment goods that are developed after the contract awarding (SCOR-process-category engineer-to-order), hardly needs the storage of feedstock
- **Network B**: Investment goods that are configured and produced after the contract awarding (SCOR-process-category make-to-order), storage of feedstock, development services, and partly also components.
- **Network C**: Consumer goods that can be delivered from stock, (SCOR-process-category make-to-stock), storage of end products.
These case studies deal with stable collaborations which are marked by a high degree of integration and a linkage of the processes, they don’t treat Virtual Organizations. As an insight gained from these case studies, Hieber and Niernhaus sum up following deficits of the SCOR-model regarding its usage in company-networks (Hieber, Niernhaus 2002, p.6).

**The model misses inter-organizational aspects**

Hieber und Nienhaus call term “Plan Supply Chain” for the process P1 of the SCOR-model misleading. For instance, the SCOR-definition includes the long-term planning of a company’s capacities, but it doesn’t support the inter-organizational planning, although the model was developed for supply chains. Also, the defined KPIs don’t describe the performance of the company-network, but of the single company (Hieber, Niernhaus 2002, p.6f).

**The information flows within the company-network remain unconsidered**

Hieber and Niernhaus criticize the lack of possibilities to model the information flows on the first two decomposition levels of the SCOR-model. This deficit essentially leads to problems in the modeling if a partner limits himself to the acceptance, handling, or the transfer of information, like it’s done in sales or service branches. The modeling of the information flows isn’t possible until the third level of the process elements. The SCOR-model also lacks the consideration of the financial flows that generate processes like tax and custom handlings in the case of a global or international network.

**Single processes that are important for logistics can’t be mapped**

Contract management and service are only partially taken into consideration by the SCOR-model. Activities like the cancellation of an order or amendments to the contract can’t be modeled, although the process “Deliver” covers some aspects of contract management. Within the framework of the Collaborative Research Center 559 approaches were developed that should integrate these missing aspects. Sources that shall only be adverted at this point are the SAP-reference-processes as well as the development efforts of the LFO in Dortmund, Germany (Hieber, Niernhaus 2002).
In reference to the points of critique regarding the applicability of the SCOR-model in company-networks, it can be referred to the work of Hieber (Hieber 2002). Hieber believes that possibilities for the description of inter-organizational planning processes as well as for the evaluation of a single company’s ability to collaborate are necessary. In order to supplement the standard KPIs, Hieber developed 3 additional performance-perspectives, and he also added suggestions for concrete KPIs:

- **Supply chain collaboration**: It means the ability to collaborate inter-organizationally in a win-win partnership and satisfy customer demands. All activities should be directed at the achievement of the global optimum of the consortium.

- **Supply chain coordination**: It covers the abilities of all consortium partners to collaborate, and to coordinate and communicate the operative processes efficiently and inter-organizationally. This assumes the place-, organization-, and time-independent access of organizations, humans, and IT-systems to all relevant information.

- **Supply chain transformability**: This perspective addresses the ability to reach a high flexibility of configuration of the process chain within an existing consortium. This ability presumes the exchange of experiences and ability just like the common realization of ideas and visions.

In order to integrate these 3 perspectives in the SCOR-model, Hieber supplements the process-category P0: Plan Supply Chain: transcorporate (see figure 25) and replenishes the intra-organizational perspective of planning of the SCOR-model with an inter-organizational view.
Even if Hieber factors the initiation and configuration in his approach, he argues on the assumption of long-termed consortia and not Virtual Organizations (Hieber 2002, p. 108). He assigns the aspect of flexibility regarding the integration of new consortium partners to the process of the continuous supply chain improvement (process element P0.3). Hieber addresses two important aspects of the network-based collaboration with its approach and proves with the help of two case studies that the SCOR-model is basically expandable and also applicable on network-based collaboration structures.

Concluding, it can be observed that the SCOR-model is able to model process chains that arise from company-networks, too, due to its basic composition. The enhancement with inter-organizational processes was noted as the main requirement on an advancement of the SCOR-model, and Hieber also contributes a suggestion in form of his approach. Explicit efforts towards the examination on how much—if at all- a high dynamism of the network configuration influences the application of SCOR aren’t currently available.
In section 3.3.3, the requirements on the IT-support of the Performance Measurement in Virtual Organizations were described. Doing this, the criteria “support of collaboration formation” and “integration level of the collaboration formation” were identified, which are combined in the matrix shown in figure 26. It allows the classification and evaluation of the Performance Measurement systems that were introduced in section 3.2.3. In the ideal case, a system for Virtual Organizations supports the analysis and the comparison of different process-chain configurations via the IT-integration of all members of the Virtual Breeding Environment.

![Figure 26: Classification of IT-systems for the support and realization of a process-oriented Performance Measurement in a matrix](image)

Considering the matrix of figure 26, it’s notable that the majority of all currently available solutions are designated for the capturing and monitoring of intra-organizational processes. Many dispose of interfaces for the automated data import. Other IT-systems also provide possibilities for the comparison of data with
Best Practice within the scope of a benchmarking. To a small extend, IT-systems support the mapping and evaluation of inter-organizational process chains, too. The data acquisition is usually carried out centrally by the Lead-Partner. IT-systems today hardly provide the possibility to identify, compare, and model different process-chain configurations. Different configuration could principally be modeled with ADOLog, but only manually. The weak point is that the problem of inter-organizational data collection of all potential consortium partners hasn’t been solved yet. To put it all in a nutshell, there is no Performance Measurement system available on the market today that supports the generation and the comparison of planning alternatives of different process-chain configurations with the complete integration of all potential consortium partners. These aspects were proven to be crucial for the application of Performance Measurement for the support of the collaboration formation in Virtual Organizations.
4 Conception of a Prospective Performance Measurement for Virtual Organizations

In this chapter, a method for the prospective Performance Measurement is developed on basis of the basic principles described in chapter 2 and 3 in order to support the collaboration formation in Virtual Organizations. Through the identification of all possible consortium partners for the realization of a specific order and through a comparison of all possible consortia, the Performance Measurement is used for the identification and evaluation of the optimal network configuration. Also, possible alternatives to the partner selection should be identified and evaluated, so that, for instance, the capacity to act of the Virtual Organization could also be assured in the case of cancellation of a partner. The implementation of this method in prototypical software is described in chapter 5.

This method utilizes the SCOR-model for the modeling of the process chains of Virtual Organizations. It was originally developed for stable supply chains, but it can partially be applied to the problem of this dissertation: Process chains basically map the bill of material of an end product to be realized. If the end product and the way of realization through a fixed consortium are unaltered, the process chain is static and can be viewed as a stable supply chain and therefore be described with the SCOR-model. At the top of figure 27, it shows an example of a process chain that is typical for stable supply chains.
The structure from that Virtual Organizations instance themselves is the Virtual Breeding Environment. In literature, it is frequently referred to as a network, because, due to its function-and resource-orientation, it disposes of a basic amount of core competencies that can be combined freely and requirement-dependently. The sequence of the processes as well as the composition of the consortium aren’t predetermined, but result from the specific requirements of the order. The configuration possibilities that arise from this basic amount of core competencies, thus the Virtual Breeding Environment, involves all basically possible partnerships, just as shown exemplarily on the bottom left of figure 27. In this case, correspondingly to the order’s requirements, a concrete process chain exists for the operation phase, just like in stable supply chains (on the bottom right of figure 27). But in contrast to stable supply chains, process chains in the Virtual Organization exist only temporally. Basically, process structures of the Virtual Organization within the operation phase and the stable supply chain can therefore be modeled with the same methods. The SCOR-model was introduced as a comprehensive and world-wide accepted approach to the modeling of inter-organizational process chains and is consequently also used for the process modeling in the methods to be developed in this dissertation.

The method to be developed discriminates categorically between management and planning activities: The management tool (see section 4.1) has the purpose of uniformly capturing the process performance and its development over the time of
each one of the involved consortium partners in form of time series during the operation phase of a Virtual Organization. This way, time series of the performance of all companies that participate in the Virtual Breeding Environment result over the course of several contracts and consortia. The management tool correlates to a conventional process monitoring for the control of the order processing in the operation phase.

Through the linkage of the processes as well as the performance data of a company and the products manufactured by this very company the Company Profiles unfolds (see section 4.2), until every member of the Virtual Breeding Environment is provided with a characteristic Company Profile. Lead-Partner and a potential consortium partners derive two advantages from the Company Profiles regarding collaboration formation: Firstly, possible product contributions of all potential consortium partners as well as their process performance are available to the Lead-Partner as a decision-making aid for the partner selection. Secondly, the members of the Virtual Breeding Environment have the opportunity to homogeneously offer their competencies as possible consortium contributions.

Finally, the purpose of the planning instrument (see section 4.3) is to identify all basically possible partnerships on basis of the product contributions that are suitable for the realization of the end product. Considering the performance to be expected of every single possible consortium, a suggestion for the partner selection is generated. Prognosis values that are derived from the key performance indicator trends of the available Company Profiles are necessary for the prediction of the performance to be expected.

The method hence bases on two instruments for the management and planning of the Virtual Organization that are interconnected via the Company Profiles. The management tool offers each member of the Virtual Breeding Environment a possibility for the monitoring of the performance of its intra-organizational processes. Besides possible product contribution of the individual members, the performance time series captured this way form the core elements of the Company Profiles. The Company Profiles are finally used for the identification and selection of consortium partners by the planning instrument. Figure 28 relates the components of the method to be developed and describes the application procedure of the method.
Management Tool

The management tool allows the Performance Measurement of the processes of every involved consortium partner during the operation phase and brings along a tool for the process monitoring. Here, the traditional application as a retroverspective Performance Measurement is meant. The time series of the KPIs that were acquainted in different collaborations now help creating the characteristic performance profiles of all potential consortium partners within the Virtual Breeding Environment. The performance profiles are then part and parcels of a Company Profile.

In the first step (a), the company-intern processes of every member of the Virtual Breeding Environment, that is all possible consortium contributions of all potential consortium partners, are modelled. These processes as possible consortium contributions represent the core competencies of the individual company and can be assumed to be stable regarding time. They can thusly be well described with the SCOR-model. The typical dynamism of Virtual Organization in form of temporary process chains arises from the order-specific combination of these (individually stable) consortium contributions.
The second step (b) are the continuous, SCOR-model-based performance test of those processes that form part of the instanced process chain during the operation phase, and the capturing of the KPIs in form of time series. This way, Performance Profiles result over time and in the course of different consortia for dissimilar contracts for all member-companies of the Virtual Breeding Environment.

**Company Profiles**

Company Profiles are created for every member of the Virtual Breeding Environment. Apart from administrative information, they mainly contain data about possible product contributions of the company, its available processes as well as a performance profile of these processes. With the aid of Company Profiles, companies are now able to describe their own potential consortium contributions uniformly and offer said within the Virtual Breeding Environment. At the same time, all these Company Profiles can be used by the Lead-Partner to identify the basically suitable consortium partners with the product contributions appropriate for an end product. The best suiting partner is then selected from this assemblage of possible partners on basis of the performance data. Like this, Company Profiles not only help the Lead-Partner to make his decision for a consortium partner, they also give him an overview over his alternatives in configuring the consortium.

**Planning Instrument**

The planning instruments serve the purpose of identification all possible planning alternatives and their evaluation for the instantiation of a consortium on basis of an end product to be produced.

In the first step (1), the iterative generation of the bill of material of the end product to be realized is carried out via the analysis of the available product contributions of all members of the Virtual Breeding Environment, using their Company Profiles.

Then (2), the identification of the possible consortium partners takes place on basis of the generated bill of material and the pool of companies that are linked to single product contributions.

Considering the processes in the Company Profiles of these potential consortium partners, all possible process chain configurations can be derived from the bill of material. After this, all basically creatable consortia compositions as well as the process chains connected to these consortia are known.

In the third step (3), targets for the partner selection are set. For this, performance perspectives are factored contract-depended regarding their relevance for the contract-fulfillment, analysis-relevant KPIs are defined, and benchmarks for minimum or ideal values of the performance are determined.
4 Conception of a Prospective Performance Measurement for Virtual Organizations

In the forth step (4), the identified possible consortia are evaluated and compared by means of the set targets. Doing this, firstly, forecast values are computed for the analysis-relevant KPIs for every potential consortium partner footing on the performance profiles. These forecast values are then measured against the target specification of the Lead-Partner and transformed into a degree of performance.

A representative Performance value that forms the basis for the partner selection can then be generated for every possible process chain and therefore also for every possible consortia through aggregation of the individual degrees of performance.

In the following sections, the method and its components are described in detail.

4.1 Management Tool

Purpose of the management tool is the acquisition of the processes and their performance of every member of the Virtual Breeding Environment with the help of the SCOR-model. Processes and performance then form a part of the Company Profile. The management tool is a possibility for the process monitoring during the operation phase that helps the individual consortium partner to execute the long-term improvement of its intern processes on the one hand, and also supports the Lead-Partner in monitoring the consortium’s capacity. Through the standardized application of the SCOR-model, the inter-organizational modeling of process chains becomes possible and is done in form of combination of the consortium partner’s processes. The main steps are summed up in figure 29 and discussed in the following sections.

![Management tool](image)

Figure 29: Management tool for performance monitoring in the operation phase of Virtual Organizations.

4.1.1 Modeling of the Processes of Each Member of the Virtual Breeding Environment and Acquisition of their Possible Product Contributions

- Modeling of the intra-organizational processes on basis of the SCOR-model
Correspondingly to the procedure required for the SCOR-model, every member of the Virtual Breeding Environment chooses those process categories from the *process view* that could be brought in a consortium as a possible consortium contribution. Exemplarily, every make-process here characterizes the realization of a possible product contribution of a company to the end product, every deliver-process the delivery to the next value-creation step, and every source-process the procurement activities necessary for the realization of the end product.

According to the definition of the SCOR-processes, consortium contributions are mainly divided into three categories: Development of uniques or, as the case may be, investment goods (engineer-to-order), commissioned production (make-to-order), and the manufacturing of mass products or consumer goods (make-to-stock). These intra-organizational processes rely on the core-competencies of the company and are temporally stable. The stable processes of all members of the Virtual Breeding Environment can later be used in the configuration of a Virtual Organization to compile inter-organizational process chains. The inter-organizational processes of a consortium partner are then factually treated as chain links within the process chain.

- **Specification of possible product contributions and their assignment to a SCOR-process-category**

Based on the defined chain links as potential consortium contributions (process view), the possible product contributions of all members of the Virtual Breeding Environment can now be defined from the *product view*. For this, all companies link their make-processes with possible product contributions. All required procurements for the product contributions can be derived from the bill of material. Figure 30 shows the relation of process- and product-view with the example of a wheel of a bicycle.
From the product-view, the wheel is a product contribution to the end product bicycle. The bill of material of the wheel plans on procurements in form of rim, casing, and tube, while the procurements themselves are product contribution of other companies to the end product. From the company’s perspective, every of its own product contributions is now connected to a correlating make-process. The integration of the make-processes in a process chain is carried out accordingly to the bill of material through deliver- and source-processes.

4.1.2 Acquisition of the Effectively Rendered Performance in the Operation Phase of a Virtual Organization

- Selection and configuration of the Effectively Rendered Performance in the Operation Phase of a Virtual Organization

The SCOR-model provides KPIs for process elements and process categories as well as for superior KPIs. In doing so, SCOR doesn’t state algorithms and units for all KPIs. This is why following acquisition rhythms are determined for the cyclic acquisition within the scope of this dissertation:

- Weekly Acquisition
- Monthly Acquisition

- Quarterly Acquisition

- Annually Acquisition

The acquisition periods can be chosen freely for every KPI and take into account the differing characteristics of business processes. For example, weekly evaluations may be appropriate in the case of processes with short cycle-time (e.g. a grinding shop), but in the case of long cycle-times (e.g. shipbuilding) annually acquisition might be more suitable. The determination of units that the KPIs are measured in can also be done individually, as long as they aren’t implied by the definitions. The ten last-captured periods of every KPI are saved for the graphic display of the KPI development over time.

- Graphic display of the developing KPIs

Literature suggests a series of graphic tools for the display of KPIs. They can generally be divided into the display of quantitative and qualitative KPIs. The SCOR-model is based on quantitative parameters. Andersen (Andersen 2002, p.158ff) presents different types of diagrams that are all summed up in figure 31.
The continuous display (A) describes the temporal changes of a measured performance, but it suggests a quasi-continuous measurement by its appearance. The discrete display (B) describes the temporal changes of a measured performance at defined points of time. Every measuring and therewith also every measured period is represented by bar. This display type is used for the visualization of KPI developing in the following. The bars also have the advantage that they can be assigned unambiguously to a period. In addition to that, they can be individually colored and carry visual information about the degree of performance. The spider-web (C) is especially useful for the integrated display of several KPIs of a performance perspective or a process. Assuming that great diameters represent a high performance, the enclosed area can be interpreted as the aggregated measure of performance regarding a perspective or a process. For this reasons, the spider-web diagram is very useful for further analyses, although time-series can’t be visualized.

Within the framework of this method, the SCOR-KPI-values of the last ten periods are each individually transferred in a time series and then displayed in form of a bar diagram (B). The developings of the KPIs that form part of the Company Profile are used in consortium planning (section 4.3) in order to predict values for the coming period.
4.2 Company Profiles

The Company Profile enables the members of a Virtual Breeding Environment to offer their own possible contributions for a Virtual Organization to potential consortium partners on the one hand, but on the other hand, Company Profiles also allow the Lead-Partner to access the consortium contributions of all Virtual-Breeding-Environment-members as well as their business process performance. So, Company Profiles are a central information carrier for the evaluation of potential consortia and the selection of consortium partners. The contents of a Company Profile are shown in figure 32.

A Company Profile contains information about four areas: The administrative data of the company in question that cover (1) the contact details like master data (name of the company, address, etc) and contact persons, (2) a Company Profile in form of a company description as well as the core competencies, and (3) information about the member status of the company within the Virtual Breeding Environment like the duration of the membership or involvement in past projects.
4 Conception of a Prospective Performance Measurement for Virtual Organizations

The second area of the Company Profiles describes the possible consortium contribution of a company within a Virtual Organization from the process perspective. These are described in form of SCOR-processes and form process chain links that later on can be combined for the building of a Virtual Organization.

The third area includes all possible product contributions of a company from the product view. Complex end products as consortium achievements of a Virtual Organization can later be described as a bill of material through iterative compilation of product contributions.

The forth area is the performance profile of a company. The performance profile comprehends the developing of all KPIs collected by the company during the last ten periods and therewith gives an overview over the performance development.

4.3 Planning Instrument

The Lead-Partner is responsible for the partner selection in the initiation phase of the Virtual Organization, and therefore also for the composition of the consortium. Purpose of the planning instrument considering this is the identification of possible consortia as well as their evaluation on basis of the end product to be realized. The Lead-Partner is to be supported in the partner selection by the planning instrument, so the consortium partners that are best qualified for the contract can be identified. At the same time, alternatives in partner selection should be made accessible to the Lead-Partner through the identification of the theoretically possible consortia. In the case of need, partners can only be substituted at short notice through knowledge and estimability of these alternatives. In turn, the availability of substitutions is crucial for the permanent assurance of the capacity to bargain and deliver, for example, by means of bridging times of supply problems. The steps to be taken in planning are summed up in figure 33 and are individually described in the following sections.
4 Conception of a Prospective Performance Measurement for Virtual Organizations

| 1. Iterative generation of the bill of material of the end product to be realized |
| 2. Identification of potential consortium partners and deduction of the process chain |
| 3. Definition of targets for the partner selection |
| 4. Evaluation of possible consortia and partner selection |

**Planning instrument**

Figure 33: Planning instrument for the support of the collaboration formation through the Lead-Partner in the initiation phase of Virtual Organizations

### 4.3.1 Iterative Generation of the Bill of Material of the End Product to be realized and the Derivation of the Process Chain

Via the Company Profiles elaborated in chapter 4.2, basically, the Lead-Partner has access to the pool of potential product contributions and to all adjunct processes of other Virtual Breeding Environment members. If the end product is now defined as root of a data tree, all potential partners that offer a required product contributions can be easily searched for and found with the Company Profiles. The product contributions are attached in form of branches (internal nodes) to the root of the data tree. Over several iterative steps, the search is newly performed for every branch until product contributions have been attached to all branches and can’t be split up any further. They are then defined as “resources” for the purpose of this method and form leafs of the data tree. Figure 34 clarifies this procedure with the example of the end product “bicycle”. The data tree finally models the entire bill of material of the end product that is later converted into a corresponding process chain.
The corresponding process chain can now be derived from the complete bill of material of the end product. In principle, all potential product contributions within the Company Profiles have been connected with a SCOR-process (compare to figure 30). The bill of material can hence be converted into a process chain through stepwise combination of the individual process chain links found in the Company Profiles. The result is a complete process chain for the realization of the end product. The conversion of the bill of material of the end product “bicycle” into a process chain is exemplified by figure 35.
In section 4.1, the procedure for the generation of the bill of material of the end product and its corresponding process chain were introduced. Because the bill of material was generated through iterative searching of the Company Profiles, there is always at least one company available as a possible consortium partner within the Virtual Breeding Environment for each and every product contribution (viz. the corresponding process chain link). Redundancies within the service offering of a Virtual Breeding Environment may also provide the Lead-Partner with several alternatives in the selection of some consortium contributions. Hence, in the next step, all possible consortium partners for every product contribution are identified on the basis of their Company Profiles. Figure 36 shows these alternatives using the example “bicycle”.

**4.3.2 Identification of Possible Consortium Partners**
The possibilities resulting from the variation on the possible consortium partners can finally be displayed in form of a data tree. All possible alternatives in collaboration formation can be read off and deduced from the data tree. The data tree for our example is described in figure 37.

Figure 36: Possible alternatives in the selection of single consortium contributions
Figure 37: Variations on possible consortium partners in form of a tree structure for the identification of alternatives in collaboration formation

All alternatives for the production of a predetermined end product are therefore known to the Lead-Partner through this data three. It too enables the Lead-Partner to identify contingency partners during the operation phase and thereby allows substituting partners that, for example, may be temporally unable to deliver or supply. In the next steps, these alternatives are evaluated regarding their performance to be expected, so as to derive a suggestion for the collaboration formation. For this, the next section defines objectives for the partner selection that later on serve for the consortium alternative evaluation.

### 4.3.3 Determination of Objectives for the Partner Selection

Basis for the evaluation of different consortium variants are the performance profiles in the Company Profiles of those companies that were identified to be possible consortium partners. In order to assure the comparability of these performance profiles, the same database must be at hand for all performance profiles. That basically means that all potential collaboration partners must measure their processes with the same KPIs. For this reason, a set of so-called *must-KPIs* to be captured regularly by every member must be defined within the scope of the Virtual Breeding Environment. Also, units and the measuring periods of the KPIs need to be constituted.
There are two different levels for the determination of objectives. On one hand and on the KPI-level, benchmarks are defined for every KPI, permitting the computation of the degree of performance. On the other hand and on the performance perspective level, the priorities of the individual performance perspectives concerning the fulfillment of the contracts are determined.

- Specification of benchmarks for the must-KPIs and derivation of a degree of performance

The degree of performance can be established on basis of the absolute KPI values through the specification of performance benchmarks in form of ideal and minimum values for every KPI. This is how all KPIs can be transformed into a percentage value and then also be aggregated for the total evaluation of a consortium (see section 4.3.4). The degrees of performance can additionally be handed out to the members of the Virtual Breeding Environment for the sake of a strategic development or a mere inter-organizational benchmarking. The appraisal of the degree of performance as well as the determination of ideal and minimum values is shown in figure 38.

![Figure 38: Definition and computation of the degree of performance](image)
The bars of the developing of the KPIs could be colored correspondingly to their degree of performance in an IT-realization of this method for a more appealing interpretation of the achieved performance of a company. In doing so, the color principle of the traffic light is borrowed for better ergonomics. It assigns the degrees of performance measured with a linear scale from 0% to 100% to a color of the color scale reaching from red (0%) over yellow (50%) to green (100%). Unlike in the traffic light scheme, this method doesn’t restrict itself to three discrete colors, but defines continuous intermediate stages (compare to figure 38).

- Filtering the performance perspectives

The KPIs of the SCOR-model are assigned to five different perspectives as described in section 3.4.1. Here, customer-oriented perspectives (reliability, responsiveness, and flexibility) and internal-oriented perspectives (costs, assets) are separated in two different groups.

The performance perspectives have to be factored in the evaluation of possible consortia appropriately and in accordance with the strategic alignment of the Virtual Organization as well as with the requirements of the customer order.

Concerning this, either all five perspectives are included, or some perspectives are filtered out by the application of a filter function and thereafter surveyed separately. In case of a filtering, exactly one performance perspective is to be chosen from each group leaving us with both an internal-oriented perspective and a customer-oriented perspective. In doing so, the internal-perspective should conform to the strategic alignment of the Virtual Organization, while the customer-oriented perspective should focus on the individual demands of the customer contract to be fulfilled.

4.3.4 Evaluation of the possible Consortia and Partner Selection

In this section, the alternatives in collaboration formation that were identified in section 4.3.2 are evaluated on the basis of the objectives set in section 4.3.3, and the consortium partner are selected for the instantiation of the Virtual Organization. For the evaluation, the over-all performance to be expected from the different, possible consortium variations is predicted. All necessary steps of the prediction are described in this section and summarized in figure 39.
The conversion of the KPIs into degrees of performance on basis of the performance objectives set by the Lead-Partner was already introduced in section 4.3.3. The computation with degrees of performance enables an easy aggregation of different KPIs through their unvarying units (percent). For this reason, it’s generally computed with performance-equivalent degrees of performance in the following.

- Prediction of performance values for the next period through extrapolation of the KPIs’ developing

In order to make a prediction for the process performance of a period still to come, first of all, the developing of each must-KPI of all possible consortium partners is extrapolated with the help of the Company Profiles. Basically, there are three entirely different methods for the prediction of developments, just as shown in figure 40.
Conception of a Prospective Performance Measurement for Virtual Organizations

Deterministic methods rest on reliable, already known future values. For example, they are quite proper for quantitative planning. Nevertheless, they can’t be applied in a prospective Performance Measurement, because future processes don’t provide calculable nor reliable data in advance. So, in principle, heuristic methods that base on appraisals, and stochastic methods, in which predictions are elaborated from the values of the past, are more convenient in this context. Appraisals require comprehensive experience with the system to be evaluated from the appraiser and are often afflicted with great incertitude. Appraisals have the advantage that they are neither costly nor laborious, and therefore quickly acquired. The stochastic methods bring forth predictions through mathematical extrapolation of known data. The utilized mathematical approaches are based on regression analyses, moving averages, or exponential smoothings. They can generate quite exact predictions about future developments if correctly applied, but they also imply a considerably bigger effort. Nonetheless, and due to their higher credibleness, stochastic methods are used for the prediction of process performance within the framework of this dissertation.

The basic characteristic of a KPI developing is to be analyzed so as to select suitable mathematical methods for the extrapolation of the KPI series: The changes of a performance over the time is compounded by three different parts, just as visualized in figure 41 (Kernler 2003, p.60ff.).

Figure 41: Qualitative parts of performance time series
According to Kernler, time series of operating data consist of the parts sais-sonality, trends, and statistically irregular fluctuations. The parts saisonality and trends describe the long-term behavior of the time series, while fluctuations also influence the measured values at short notice. Trends can be captured mathematically by exponential smoothing (Kernler 2003, p.69), and there are also specific procedures for the description of saisonalities like the multiplicative seasonal model that is frequently applied. Time series that exclusively consist of fluctuations can be described by the moving average method.

The estimation of a KPI value is a short-termed prediction. While the influence of trends and saisonalities is usually negligibly small in short-termed predictions, fluctuations have to be smoothed, so plausible, short-termed predictions of time-series can be made. Statements about the middle- or long-term behavior of a time series should not be made, because these effects are usually negligible for the planning horizon of a single contract. Therefore, the moving average method is a sufficient procedure in this implementation.

Figure 42 shows the exemplary calculation of a predicted degree of performance of a KPI from a time series with the help of the moving average method.

\[
E = \frac{\sum_{P=1}^{10} E_P \times W_P}{\sum_{P=1}^{10} W_P}
\]

If \( W \) is constant, the degree of performance is the arithmetic mean of all values of \( E_P \)

\( P \) : Period
\( W_P \) : Weight-balancing factor for period \( P \)
\( E_P \) : Degree of performance in the period \( P \)
\( E \) : Degree of performance forecast for the next period

Figure 42: Prediction of a degree of performance for a KPI through extrapolation of a time-series.
All degrees of performance of the last 10 periods are multiplied with a weight-balancing factor. This weight-balancing factor can be freely chosen for every period. The resulting products are then summed up. In this context, an individual selection of weight-balance factors allows for a set of different assumptions:

A constant weight-balance factor brings forth the arithmetic average of all degrees of performance and implies an expected value for the future on basis of a constant average-performance in the long-run.

The determination of individual weight-balancing factors for each period (moving average) assumes that not all values measured in the past are equally representative for the future. If, for example, the actuality is taken as a measure for balancing (the more recent, the more weight; $W_p > W_{p-1}$), it actually implies that the more recent periods rather correlate with the expected future than more remote periods. Any whole number between 0 and 10 (a percent equivalent in decimal steps) can be chosen as weight-balancing factor for each period.

The standardization of the weight-balancing factors is then carried out by the computation that is demonstrated in figure 42. In this method, all weight-balancing factors sum up to a 100%-equivalent. Now, their percentage share of the 100% equivalent is calculated for every single weight-balancing factor and thereafter used for the mathematical weighting of the respective degree of performance. The results of this calculation are the predicted degrees of performance for all individual KPI developments regarding the upcoming period.

- Aggregation of the predicted degrees of performance within the companies to the Company Indicator

Goal of this step is the aggregation of the predicted degrees of performance to a single Company Indicator for every possible consortium partner. The Company Indicator divides between a customer-oriented and an internal-oriented component in accordance with the performance perspectives of the SCOR-model. The Company Indicator is defined as a two-dimensional vector for this very reason. Its components are aggregated performance values, one for the customer-oriented and the other for the internal-oriented perspective, and characterize the expected performance of a possible consortium partner within a planned consortium.

The priority setting of the performance perspectives (compare to section 4.3.3) is factored in the aggregation of the predicted degrees of performance. Figure 43 shows the basic procedure applied for the calculation of the Company Indicator.
Figure 43: Calculation of the Company Indicator from the predicted degrees of performance of the must-KPIs

In the **first step**, the predicted degrees of performance of the respective must-KPIs are aggregated via the arithmetic average method for each of the five performance perspectives. The result is an averaged degree of performance for every performance perspective. Its calculation is displayed in figure 44.

Figure 44: Calculation of averaged degrees of performance

- $E_i$: Degrees of performance forecast for one obligatory KPI
- $E_g$: Average degree of performance for one performance perspective
- $n$: Number of predetermined obligatory KPIs for one performance perspective
The **second step** is the aggregation of the averaged degrees of performance to a Company Indicator. The Company Indicator is a two-dimensional vector and has two components: one value for the customer-oriented and another for the internal-oriented performance perspectives. Depending on the objectives (filtering of performance perspectives), the individual performance perspectives are factored in with the respective filter values \( f \). The generation of the Company Indicator is shown in figure 45.

![Figure 45: Calculation of the Company Indicator](image)

The Company Indicator consists of reliability, flexibility, and responsiveness for customer-oriented performance, and cost and assets for internal-oriented performance.

Now, there is an aggregated performance value that describes a potential consortium partner with the help of a performance prediction. The display format (vector) allows the discrimination between customer-oriented and internal-oriented performance (compare to figure 46). The Company Indicator forms the basis for decision-making in the partner selection.

![Figure 46: Display of the Company Indicator as a vector](image)
• Calculation of the over-all performance of a consortium

In the third step of the analysis, finally, the achievable over-all performances are calculated through aggregation of the Company Indicators of the respective involved consortium partners for all basically possible consortia. In doing so, the components of the vector aren’t treated equally.

Figure 47: Aggregation of the components of the Company Indicator vectors within a consortium for the calculation of the over-all performance of a consortium

From the customer-oriented perspective, the lowest performance of all consortium partners is also the over-all performance of the consortium. This means that- regarding the performance-perspectives reliability, flexibility, and responsiveness- the consortium performance never exceeds the performance of its weakest link (Reiner 2002). For example, the poor supply-reliability of a consortium partner automatically reduces the supply-reliability of the whole consortium, because the realization of the end product relies on the consortium contributions of all partners. Hence, the sensitivity for a low consortium performance increases together with the size of the consortium, simply because the customer-oriented performance is determined by only one partner, the weakest, and more companies are involved in the performance creation.

The over-all performance of a consortium regarding the internal-oriented perspective results from the arithmetic average of the performance values of all consortium partners. So, for example in the case of costs and assets, it’s possible for a consortium partner to compensate his own bad cost situation
with the good cost situation of his consortium partner. Big consortia are hence more resistant towards the influence of a single partner then small consortia regarding the internal-oriented performance.

The over-all performance of a consortium can thus be displayed as two-dimensional vector, just like the Company Indicator. Figure 48 demonstrates the calculation of the over-all performance.

<table>
<thead>
<tr>
<th>Consortium partner</th>
<th>Company Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partner 1</td>
<td>U_{k,1}</td>
</tr>
<tr>
<td>...</td>
<td>....</td>
</tr>
<tr>
<td>...</td>
<td>....</td>
</tr>
<tr>
<td>...</td>
<td>....</td>
</tr>
<tr>
<td>Partner n</td>
<td>U_{k,n}</td>
</tr>
</tbody>
</table>

\[ \bar{G} = (G_k; G_i) = \left( \min(U_{k,m}) ; \frac{\sum_{m=1}^{n} U_{i,m}}{n} \right) \]

\( n \): Number of consortium partners  
\( U_{k,m} \): Customer-oriented component of the Company Indicator of Partner \( m \)  
\( U_{i,m} \): Internal-oriented component of the Company Indicator of Partner \( m \)  
\( \bar{G} \): Vector of the Over-all Performance  
\( G_k \): Customer-oriented component of the Over-all Performance  
\( G_i \): Internal-oriented component of the Over-all Performance

Figure 48: Calculation of the over-all performance

All basically possible consortia identified in section 4.3.2 can now be compared using the over-all performance. The consortia are firstly ordered by their custom-oriented over-all performance. The second arrangement criterion is the internal-oriented over-all performance. The reasons for this arrangement order are the prior goal of Virtual Organizations, the ideal fulfillment of the customer’s wishes, on one side, and on the other side the sensitivity of the customer-oriented performance to the influence of single consortium partner. This way, the Lead-Partner can estimate the possible alternatives in collaboration formation regarding their expected over-all performance. The consortium with the highest customer-oriented over-all performance and with high internal-oriented over-all performance has the status of the prioritized suggestion and is the result of the planning instrument.
5 Development of an IT-Based System for Prospective Performance Measurement

In this chapter, the method developed in the previous chapter for the prediction and evaluation of the expected over-all performance of different consortia of Virtual Organizations is implemented in web-based software. Web-applications appear in form of a set of generated web-sites and their content can be influenced and modified interactively. These generated web-sites often hide complex software systems. So, in the last few years, the discipline of the web-engineering was developed to support the development of web-applications, extending the traditional procedures in software-engineering by characteristics of web-applications (e.g. their possibilities of navigation). Figure 49 presents an established web-engineering procedure-model that was elaborated by Kappel et al. According to them, the application-development can be described by the three axes phases, levels, and aspects. The manifestations of the axes levels and aspects are described for every development phase within the scope of this chapter.

![Figure 49: Procedure of web-application development according to Kappel et al.](Kappel 2003, p.15)
• **Phases**

In the first phase of the software-engineering, the *requirements analysis*, the requirements imposed on the system to be realized are pinpointed and described. These are then transferred in the architecture and modeling in the *design phase*, and therewith serve as methodic basis for the concluding *implementation phase*. The phases are the main arrangement order criterion of the development process and shall therefore set the order of this chapter.

• **Levels**

The three levels content, hypertext and presentation are the manifestations of a web-application.

The *content level* describes those parts of a web-application that usually have to provide the user with information. For this, the data is edited and then presented in form of tables, texts, or figures, or new information is dynamically generated from available data as well as user inputs and displayed.

The *hypertext level* describes the possibilities of navigation within a web-application. Hypertext-documents consist of information units (node) that can be accessed via an URL and hyperlinks that allow jumping from one node to another. The movement of one user through the information area of a application is either done by browsing or targeted search, so-called queries or guided tours that lead the user through the application.

The *presentation level* describes the user interface of the web-application and has a high status in the application development because of its great creative possibilities. Important criteria are the appearance, esthetics, and the operability of an application. The presentation level is documented in this dissertation by screenshots in the chapter on implementation.

• **Aspects**

The configuration of the described levels is executed in accordance with the aspects *structure* and *behavior*. While the structure view focuses on the objects of a level with their attributes and connections among each other, the level behavior enlarges on the functionalities of each level.

The order of this chapter is oriented to the three phases of the software engineering. Section 5.1 initially describes the requirements analysis and then reasons the decision for the development of a web-based software. Architecture and system design are then modeled in section 5.2, leading to the implementation of the system in section 5.3 that is pictured by commented screenshots. The development work described in this chapter is the outcome of a dissertation that was supervised by the author within the framework of the creation of this dissertation (Kracke 2005).
5 Development of an IT-Based System for Prospective Performance Measurement

5.1 Requirements Analysis

This section treats the technical requirements imposed on the software system on basis of its purpose. The requirements analysis serves the preparation of the design and implementation phase that have following subjects: the determination of an architecture, the modeling of the draft divided into releases, and finally the selection of a suitable implementation technology. The whole list of requirements in story-format is found in the appendix. The procedure of the requirements analysis is visualized in figure 50.

![Diagram](image)

Figure 50: Procedure of the requirements analysis

The later development of the architecture design mainly depends on the chosen application type, while the division of the system design into releases is oriented to the core functions of the system. For this reason, firstly, the basic requirements of the systems are analyzed, so that the application type and core function can be derived. The core functions then serve as the basis for the release planning which in turn is the basis for the modeling of the complete system. Requirements are individually formulated for every release and later implemented in form of small units. Requirements analysis and the system design derived from the first are carried out in iterative steps and temporally parallel in accordance with the Twin-Peaks-model.
5.1.1 Basic Requirements

First objective of the requirements analysis is the determination of the application type for the preparation of the architecture design (subsection 5.1.1.1) as well as the identification of the core function for the preparation of the release planning (subsubsection 5.1.1.2). The requirements from which these two aspects can be derived from are called basic requirements.

The purpose of the IT-system to be developed is the generation and evaluation of planning variants in the collaboration formation of Virtual Organizations through the acquisition and analysis of KPIs on the basis of the SCOR-model. The system’s purpose is to create the bill of material of a specific, given end product iteratively from the potential product contributions of possible consortium partners. The bill of material then serves as a basis for the identification of possible consortia and for the evaluation of their expected over-all performance.

The IT-System to be developed should be internationally as understandable as possible, because it must be assumed that the members of the Virtual Breeding Environment as users of the IT-system will be scattered around the world and with international. The navigation and interface shall therefore be in English.

5.1.1.1 Application Type

Following requirements must be considered for the determination of the application type (web-application or conventional application):

- **Database System**: One of the main purposes of the software system is the saving and providing of the performance data of the Virtual-Breeding-Environment-members. The software system should be build upon a database management system (DBMS) that reliably and safely manages all relevant data. The utilization of a DBMS also allows the import and export of data from other systems (e.g. integration of production planning and control systems).

- **Network-compatibility**: the integration of many, possibly globally scattered, companies in a Performance Measurement demands possibilities to access the system from anywhere via a shared IT-network. This way, the Performance Measurement data doesn’t have to be collected and implemented centrally, but can be captured and provided by the companies themselves.

- **Platform-independence**: The client’s side of the application should be created for platform-independent usage in order to enable all companies in the Virtual Breeding Environment to use the software system regardless of their size or current IT-structure.
These basic requirements would be met ideally through a web-application realization. Web-applications can be designed to be platform-independent through server-side implementation of the needed technologies and they are also network-compatible through the usage of the internet as infrastructure. Finally, the professional data base can be provided through the integration of a DBMS in the architecture. Also, the security of the data can be easily assured by the usage of encryption-technologies of the internet (TLS/SSL). The software is realized in form of a web-application for stated reasons.

5.1.1.2 Core Functions

The core functions of the system must be defined after determining the application type, and they also frame its basic scope of functions for the fulfillment of the application’s purpose. The developmental work packages derived from these core functions can then be merged to releases within the scope of the release planning. Following core functions result from the application’s purpose:

- **User and company administration:** The system is to manage the data of several companies and must therefore support multiuser usage. At the same time, it should grant access to different users of the same company with different user rights. For this reason, the system must also include an access control in form of an authorization and authentication system.

- **Process reference model:** The description of the company processes as well as the KPI-acquisition must underlie a uniform reference model (SCOR) in order to guarantee inter-organizational comparability of data.

- **KPI-acquisition:** The KPI-acquisition and the connected acquisition configuration (period, determination of dimensions, etc.) are the most important functions of the system, because the measured data forms the basis for the content to be displayed through the web-application. The system must dispose of an interface for the data collection and the acquisition configuration, too.

- **Identification and analysis of possible consortia:** The system’s output to be generated is the identification of possible consortia that are compiled from Virtual-Breeding-Environment members for the creation of an end product. The evaluation and selection is then carried out on the basis of the expected over-all performance of all basically possible consortia. The method for a prospective analysis (section 4.3) of the over-all performance of a consortium must therefore be implemented in the system.

- **Product catalogue:** The identification of possible consortium partners foots on the bill-of-material generation of the end product to be created. There are
several (at least one) potential consortium partners connected to each included product contribution, and the system must hence manage a whole product catalogue that contains all possible product contributions of all members of the Virtual Breeding Environment.

5.1.2 Release Planning

To start the release planning, the five identified core functions of the system are now logically grouped up and then assigned to one of the two releases. In doing so, the definition of the releases is oriented to the division of planning and management tool introduced in the method development of section 4. In this context, Release 1 covers the company configuration and the data acquisition (management tool), and release 2 covers the identification and the analysis of possible consortium partners (planning instrument). Figure 52 shows the assignment of the core functions to the releases and illustrates logical correlations.

![Figure 51: Overview over the release planning](image)

Release 1 contains all the core functions necessary for a data acquisition tool that can be used by several users. Besides the user and company administration, the KPI-acquisition and configuration is the main focus of this release. The KPI configuration uses the process reference model (SCOR). The product management (product catalogue) is included in Release 1, too. Release 1 therewith covers the majority of the functionalities of the system.

Release 2 contains the identification of possible consortia and their analysis that is the prediction of the over-all performance. This release holds the major part of the application logic, because of its algorithms to be implemented.
The following sections present and describe the requirements of the individual releases.

### 5.1.2.1 Release 1: Company Configuration and the Data Acquisition (Management tool)

The four core functions of Release 1 serve as arrangement order criteria of the single units in system design (section 5.2), because the respective functionalities to be developed can mostly be developed separately. So, the release requirements are described one by one and in line with the core functions.

**User and company administration**

The requirements linked to network-compatibility lead to the necessity of an access control as well as to a user administration. A corresponding authorization and authentication system must be specified. Figure 52 uses a use case diagram to illustrate the authorization concept as well as the rights of the possible roles.

![Figure 52: Use case diagram of the authorization concept](image)

**Process reference model**

The SCOR-model is the methodical background for the process description and KPI-acquisition. The process descriptions of the three decomposition levels of the
model (process types, process categories, and process elements) are to be implemented in the software together with their associations and individual KPIs that again incorporate KPI-perspectives. The SCOR-symbolism should be used by the software for the presentation of the model. Because the SCOR-model is continuously advanced by the SCC (Supply-Chain Council), the version implemented in the tool should also be modifiable, so that updates and changes of future versions can be integrated by the Super Administrator right away.

**KPI-acquisition**

The KPIs to be collected are associated with the SCOR-model. In the configuration of the model for a specific company, KPIs are selected and the KPI-acquisition interval is set for the cyclic data collection. The IT-system documents the KPI history for the last 10 periods captured, allowing to factor in the development of the KPIs. The maturity of a KPI input should be notified to the user through a prompt in order to avoid data gaps and to support the KPI-acquisition. The manual KPI-acquisition is sufficient for the prototypic realization, but must be substituted by an automatic data import for application in industrial practice.

**Product catalogue**

All potential product contributions managed in the database of the IT-system are listed in the Product catalogue. All of these product contributions that are listed can be linked to any number of companies. This product catalogue is the database for the bill-of-material generation of an end product.

### 5.1.2.2 Release 2: Identification of Possible Consortia and their Analysis (Planning Instrument)

The data needed for the evaluation function of release 2 are mainly given through data that was captured in Release 1. Additionally, the Super Administrator has to globally determine the KPIs of interest that are to be captured by all members, and the individual KPI-acquisition intervals in order to achieve uniform databases for all partners.

Based on the end product’s bill of material, the **identification of possible consortia** is carried out by the Super Administrator. For this purpose, the possible consortium partners regarding every single product contribution of the bill of material are to be identified.

The **analysis** is finally based on the calculation of the over-all performance of the basically possible consortia and their ranking. The calculation of the over-all performance is made as described in section 4.3. The analysis outcome is the favored consortium and also the possible alternatives with their predicted performance.
5 Development of an IT-Based System for Prospective Performance Measurement

5.2 System Design

Subject of this section is the creation of an *IT-system architecture* as well as the *modeling* of both releases regarding the levels content, hypertext, and presentation. The design is to be understood as a preparation for the implementation phase in section 5.3. Within the framework of this dissertation, only the central structures are modeled within the scope of hypertext modeling, while a documentation of the presentation modeling is completely left out, because the implementation is comprehensively described in section 5.3.

5.2.1 Architecture Design

The architecture can be developed on the basis of the determined requirements in the appendix, and it is displayed in figure 53. It is based on the generic client-server architecture of web-applications (Kappel 2003, p.86).

The requirements of the database system are met through the embedding of a database server. The demanded platform-independence necessitates a server-side implementation technology, so the web-server must be complemented by a corresponding component. The selection of a URI-dealer as server technology for the session-tracking avoids client-side plug-ins, because the database server is exclusively accessed from the server. At the same time, the URI-dealer should be able to run extern applications that are needed for the creation of graphics in the process of visualizing the KPIs. The fulfillment of the safety requirements is achieved through the expansion of the web-server by encryption technologies. Indeed, cor-
responding expansions are also required on the client-side, but they are usually already integrated in all established browsers and won’t be treated separately.

5.2.2 Release 1

Release 1 contains the four core functions *KPI-acquisition, process reference model, user and company administration* as well as *product catalogue* that are modeled with the three levels content hypertext and presentation in this section. The core functions are modeled together, if possible.

![Figure 54: Release planning: Release 1](image)

### 5.2.2.1 Content Modeling

The data structure that can be derived from the four core functions of Release 1 is modeled in this section. The visualization of the core functions is carried out with the help of an UML class diagram. It’s passed on modeling the content-ratio within the framework of this architecture design because of the low complexity of the application logic.
Figure 55 shows the data structure for the configuration of the SCOR-model for a company and the KPI-acquisition. Besides the KPI values, information about the identity of the company and the user as well as company-specific SCOR-model configurations are saved in the course of the KPI-acquisition. The individual classes are logically summarized in blocks.

The left block contains the classes **Company** and **User**. Companies and logged-on users are identifiable with these classes. The class **Company** represents describing information about the registered company and serves as a reference point for all the rest of the data. Every company has at least one user assigned to it, whose data and login information are summed up in the class **User**.

The right block covers the classes **Process** and **Metric**, which contain the components of the SCOR-model. The processes and KPIs of the SCOR-model and its assignments are fully described by these classes. An object of the class **Process** can either represent a process category, a process element or an enable-process of the SCOR-model, depending on the value of the field **type**. The assignment of process elements to the higher-ranked parent class process category is triggered by equal content in the field **processcategory**. Any number of the predetermined KPIs may
be related to any process element or any process category via the field \textit{process\_ref} of the class \textit{Metric}.

The middle block comprises the classes \textit{Company Process}, \textit{Period}, and \textit{Data}. Here, the company-specific process model is filed on basis of the reference model and the values for the chosen KPIs are queried and saved. Every company can have any number of process categories. The process categories come from the process reference model with which also the process elements are identifiable. An object of the class \textit{Company Process} is created for every assigned process category and unambiguously assigned to a company in the class \textit{Company} via the field \textit{company\_id}. For the configuration of the data acquisition, an object is produced in the class \textit{Period} for every KPI to be captured. This object then describes what KPI of which process is to be captured, and determines the periods (intervals) of the data acquisition as well as the units of the KPIs. The filing of the data itself is done in the instances of the class \textit{Data}. In it, besides the value of the KPIs, the date of capturing, the user (capturer), and the acquisition period of the values are documented. The class \textit{Period} can hold 10 data-entries (of the last 10 periods) at max and they are continuously overwritten.

![Class diagram for the acquisition of the available product contributions of a company and their required supplies](image)

Figure 56 shows the data structures for the assignment of product contribution to the processes of a company and the determination of the required supplies for this product contribution.
The class **Product** servers the acquisition of all product contributions managed in the database and represents the so-called product catalogue of the system. Product contributions can either be created by an administrator or a user of the registered company. The assignment of a product contribution of the product catalogue to a company is done by generation of an instance of the class **Company Product**. This entry links a product contribution unambiguously to a company through the field `company_id` and a product contribution to a process category of this company through the field `companyprocess_id`.

As many supplies as needed may be assigned to every individual product contribution for the creation of the bill of material of an end product. For this, a list of user-defined length that bears the needed supplies is created in the class **Product Requirements**, and then stored in the field `required component`. The list is assigned to exactly one entry in the class **Company Product** by the field `companyproduct_id`. The classes **Company Product** as well as the class **Product Requirements** both reference objects of the class **Product**. Therefore, there is no data-technical separation between product contributions and the required supplies.

### 5.2.2.2 Hypertext Modeling

In this section, the structure modeling of the hypertext behavior of Release 1 is presented. It’s abstained from the nomination of the links with the stereotype `<navigation link>` for reasons of clearness, although it is true for all links between the navigation classes of the hypertext models.

The central functions for the opening of a profile by a company include two tasks: The configuration of the SCOR-model as well as the recording and configuration of the potential product contributions. The possibilities of navigation for the execution of these tasks are illustrated in following structure models.
Figure 57 shows the navigation structure model of the content classes for the management of the user- and company master data as well as the configuration of the SCOR-model (configuration of processes as well as determination of parameters for the KPI-acquisition).

Initial point for all possibilities of navigation is the class Company. Although, it hasn’t got a central importance for the presentation of the content, because it exclusively contains information about the master data of a company (name, address, etc.), this class does serve as an identification criterion for the assignment of the data managed in the system. So, for example, the KPIs aren’t assigned to a registered user, but to his company.

An Administrator is able to access the Users via the link user for the user administration. Additional data isn’t necessary. The administration of company master data is handled this way, too, except it uses the link company data.

The navigation within these levels of the SCOR-model is influenced by two content categories (compare to figure 55). The data of the classes Process and Metric that describe the reference model are responsible for the basic navigation control between the navigation classes. The possibilities of navigation then result from the...
data of a company-specific concrete SCOR-model configuration that is filed in the classes *Company Process* and *Period*.

As it can be perceived from the displayed classes, there is no data-technical separation of process categories and process elements in the content classes. Both are saved as objects of the class *Process*. Assigned process elements become available with the selection of a process category. A navigation from a process to the navigation class *Metric* is possible in the selection and configuration of KPIs. Configured KPIs can be directly accessed via the classes *Periods*.

![Diagram of product configuration](image)

Figure 58: Structure model of the product configuration

The **configuration of the product contributions** modeled in figure 58 is a task that falls within the scope of the user-group Administrator. It includes the saving of a product contribution through the Administrator of a company and the assignment of required supplies. The product contributions that are saved by registered companies are centrally filed in a database and therewith create the inter-organizational product catalogue of the system. It pools all potential product contributions of the members of the Virtual Breeding Environment.

Again starting with the navigation class *Company*, the link *own product contributions* leads the Administrator to the possible product contributions of the currently registered company and allows to look at the supplies (represented by the class *Product Requirements*) required for this product contribution. The link *possible*
supplies serves the configuration of one’s own product contributions. This way, additional supplies may be assigned to a product contribution. Finally, the Administrator can look at the whole product catalogue via the link *Product Catalogue*.

### 5.2.3 Release 2

After the majority of the core functions were already modeled in the previous chapter, the modeling of the fifth core function “identification and analysis of possible consortia” (see figure 59) will be topic of this section.

![Diagram showing release planning: Release 2](image)

**Figure 59: Release planning: Release 2**

#### 5.2.3.1 Content Modeling

The data structure described in this section serves as a basis for the procedure presented in section 4.3 that being the identification and analysis of possible consortia. Figure 60 also represents the content modeling for the creation of the tree structure of possible consortium partners.
Initially, an entry in the data tree to be generated is created in the class *Result*, allowing the identification of the tree and all of its nodes via the *result_id*.

Starting point of the tree generation is the end product to be created, represented by the class *Company Product*. The class *Result Companyproduct* is used in order to add this product to the tree in form of a node. Within stated class, every object is furnished with the ID of the tree entry and with the referenced entry in the class *Company Product*.

In the second step, all supplies needed for the end product are found with the help of the class *Product Requirements*. By using the field *product_id*, the entries in this class refer to entries of the product catalogue of the class *Product*. These references are integrated in the tree together with objects of the class *Result Product*.

When all required supplies are identified at last, the possible consortium partners regarding these supplies are searched. Doing this, all entries in the class *Company Product* that bear the ID of the required supplies as *product_id* are searched for. Objects of the class *Company Products* that were found this way are integrated in the class *Result Companyproduct*. In the next step, the recently added product contributions are checked for their own required supplies. This way, the bill of ma-
terial emerges iteratively. In the end, every product contribution is linked to at least one possible consortium partner via its respective ID.

5.2.3.2 Hypertext Modeling

Thanks to the fact that the created data tree may be approached from many sides, a user-specific display of the results is possible. Ordered as a multi-level bill of material of a product or as a list of the consortium partners with their respective product contributions, different arrangement order criteria may be chosen for the display of the results. Figure 61 shows the access model of the data tree.

![Access model of the evaluation results](image_url)

Figure 61: Access model of the evaluation results
The index *Data trees* gives an overview over all data trees generated within the calculation and saved in the data base, and it’s also the starting point in the evaluation menu. Following display variants are possible.

- **Ordered by product contributions** (tree K): Only those consortium partners who altogether render the highest over-all performance are shown for every product contribution. The list is ordered in accordance with the bill of material of the end product and suggests one consortium partner for every product contribution.

- **Ordered by companies** (tree U): Only those consortium partners who altogether render the highest over-all performance are shown for every product contribution. The list is ordered by consortium partners and names the consortium partner’s product contributions to the end product.

- **Complete tree**: Ordered by the bill of material of the end product, all possible consortium partners are listed for every product contribution and ordered by the value of their Company Indicator. This is how the Lead-Partner gets an overview over possible alternatives in collaboration formation and qualified contingency positions in partner selection.

### 5.3 Implementation

After the design of the system, now, in the first step of the implementation, the *utilized technologies* must be chosen for the implementation. The decisions to be met result from the requirements of the architecture design. Aspects of the user-interface design are not a direct subject of this work, and therefore aren’t treated.

#### 5.3.1 Utilized Technologies

The architecture design presented in section 5.2.1 exclusively plans on server-side implementation technologies for attaining the demanded platform-independence and an easy integration of the IT-structure in a company. The components displayed in figure 62 are due to this fact. As a principle, gratis open-source solutions were preferred in order to keep the development inexpensive.
5.3.2 Release 1

The order of the core functions to be implemented results from their logical usage order. The implementation is then carried out in single units. First step is the login of the user. Accessible functionalities, hence authorizations, are determined through authentication. These actions are represented by the core function user and company administration. In the second step, the SCOR-model is configured by modeling the processes of a company as well as selecting the KPIs to be captured. These actions are covered by the core function process reference model. In the third step, the values of the chosen KPIs must be captured and graphically displayed. These actions are realized through the implementation of the core function KPI-acquisition. The forth step includes the capturing of the product contributions, the linkage to their required supplies correspondingly to their bill of material, and the assignment of SCOR-processes to every product contribution. These assignments serve as the basis for the evaluation function of Release 2 and are realized along with the implementation of the core function product catalogue.

5.3.2.1 User and Company Administration

The implementation of the core function user and company administration is carried out in three units. Their result is documented in this very section.
• Authentification

In order to check the identity of a user, he must login the server with his access data, which is compared with the server-side access data.

• Authorization

The multi-level user concept that was defined in the requirements analysis assigns individual user rights to every user group. Every user may utilize exactly those functions that come with his group. This is put into reality by fading out those functions that require a higher authorization level.

• User and company administration

The objects of usage that must be administrated in the course of the registration are users and companies. The opening, changing, and deletion of user and Company Profiles are part of the administration, just like the assignment of user rights.
Unit: Authentification

The identification of the logged-in user is done via a session tracking that uses URL-rewriting. This way, all data and requests submitted to the server can always be assigned to a user without ambiguity. Figure 63 shows the realization of the login procedure: The login form (figure 63, left) is substituted by the navigation menu (figure 63, right) after the successful login. The cockpit (right) emerges as a welcome page and brings about a list of mature KPI inputs as well as a graphic overview over KPIs (displayed KPIs may be chosen). The headline displays information about the logged-in user, his company, and also his user group.
Figure 64: Navigation menu with differing access rights that depend on the authorization level.

Figure 64 presents the navigation menus for different authorization levels. The **Super Administrator** (left) disposes of the full functional range, especially the analysis function in the group *My Network*. He also has the rights to update the SCOR-model to future versions, because he may use the functions *Edit Process terms* and *Edit Metrics* in the group *Tools*. The **Company Administrator** (middle) has got the right to model the processes of his company in the group *My Company* via *Configure Model*, and he also may administrate the users of his company with the function *User Management*. One’s own product contributions can also be administrated via the group *Product Catalogue*. Simple **Users** (right) have the rights to insert data and display as well as view KPI diagrams in the *Cockpit*. In addition to that, messages can be sent and received via the group *User Options*. 
Unit: User administration

The user administration is reached via the menu entry User Management. Its appearance follows the list structure shown in figure 65.

![User Management List](image)

Figure 65: Screenshot of the user list

With the help of the user list, users can be added (empty input fields in the last row and button Add), edited (button Details), and deleted (button Delete). The data Login, Name, First Name, and Email are transmitted to the http-server using a set web form and then saved in the database. The newly registered user thereafter receives an automatically generated random password at the stated email address. This very password now allows the user to log in the system for the first time.

An example of the detail view of the user profile is provided by figure 66. Besides the contact information, it also includes statistic information about the usage behavior like the number of submitted KPI values, day of the last login or day of the profile creation. The company administrator can only change those values of a registered user that don’t influence his authentication. That means the login and the password can’t be altered by the company administrator.
Unit: Company administration

The company administration is designed just like the user administration. It gives the Super Administrator a tabular overview over the registered companies in the system. If a new company signs up, the account of the first user is equipped with Company Administrator rights. If a company is deleted from the database, all Users that are assigned to this very company are also deleted in order to avoid unused user profiles.

5.3.2.2 Process Reference Model

The core function process reference model assumes the implementation of the SCOR-model in the database as well as its graphic editing for the navigation within the model on the one hand, and on the other hand it implies the configuration of the model for the display of company-specific processes. The database structures that are necessary for this were already presented in section 5.2.2.1 and will therefore not be discussed any further at this point. This section hence encloses on the configuration of the SCOR-model via the user interface. The process configuration covers the selection of all those process categories of the SCOR-model that are relevant to a company as well as the establishment of KPIs for the individual processes.

Figure 66: User details: contact and statistic information

Statistic information about the usage of the system

Contact details of the user
Figure 67: Example of a company-specific configuration of the SCOR-model

Figure 67 shows an example of a company-specific configuration of the SCOR-model that’s basically based on fading out unused process categories. The drop-down-menu on the top of the figure is the tool to fade entries in or out. The sum of entries in both rows represents the whole SCOR-model. The adding of a process through the menu Add a Process Category removes the chosen object from the list and adds it to the list Remove a Process Category. The configured processes are visualized by described graphic components (at the bottom of figure 67).
5.3.2.3 KPI-Acquisition

The functions that are linked to the KPI-acquisition can be divided into three units:

- **KPI configuration**

  The KPI configuration includes the selection of SCOR-KPIs for the evaluation of process categories and elements, the determination of an acquisition period, and the initial period as well as the definition of a unit for the KPI values to be captured.

- **KPI capturing**

  This function contains the generation of a list of mature value inputs for the configured KPIs in dependence of their respective acquisition periods as well as the data input function.

- **Must-KPIs and limits**

  In order to assure the comparability of all partners who participate in the Virtual Organization, so-called must-KPIs may be established by the Super Administrator (the Lead-Partner in the Virtual Organization). These must-KPIs are obligated parts of the KPI-acquisition of every single company of the Virtual Breeding Environment. Just as in KPI configuration, the Super Administrator determines acquisition periods and units and also defines worst and best values as benchmarks that then help measuring the actually achieved KPI values of the partners against the target values. These actually achieved degrees of performance are assigned to specific signal colors, following the traffic light scheme explained in section 4.3.3 (red= bad, yellow= average, green= good). The bars of the diagrams in the cockpit are also colored in accordance with stated principle.
Unit: KPI configuration

The Company Administrator employs the function process navigation via the navigation menu *Configure Model* to view a list of the KPIs available for the individual objects in process categories and elements. An exemplifying list is shown in figure 68.

![Figure 68: List of the KPIs of a process element](image)

The system allows the selection of following acquisition periods: *week*, *month*, *quarter*, and *year*. With the function *Show all configured metrics*, the administrator can also attain a synoptical table of all configured KPIs.
Unit: KPI capturing

After the configuration of the KPIs, every user is authorized to capture values for the queried KPIs and to file them in the system. In order to advise the user of mature data inserts, it was already decided in the design of the system to query the data on the welcome page Cockpit. For querying the values in accordance with their individually configured periods, three more details are needed: time of the last data input for a KPI, chosen period for this KPI as well as the current time. The maturity of a value regarding their different acquisition periods arises from following rule:

<table>
<thead>
<tr>
<th>Acquisition Interval</th>
<th>Date of Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week</td>
<td>First day of the calendar week (Monday)</td>
</tr>
<tr>
<td>Month</td>
<td>First day of the month (1th of every month)</td>
</tr>
<tr>
<td>Quarter</td>
<td>First day of the quarter (01/01, 04/01, 07/01, 10/01)</td>
</tr>
<tr>
<td>Year</td>
<td>First day of the year (01/01)</td>
</tr>
</tbody>
</table>

During the acquisition of KPI values, a time stamp that carries the date and time of capturing is saved together with each value. With the help of this time stamp, it can be checked if a new period has already begun and therefore if an input is mature.

Unit: Must-KPIs and limits

Correspondingly to the KPI configuration, the Super Administrator can determine and configure must-KPIs for every process category and process element. These KPIs must be captured by every member of the Virtual Breeding Environment during the integration of the respective process. This way, a data pool that is uniform within the Virtual Breeding Environment is provided for every process. This is necessary for the comparability of data in the generation of process chains. The designated selection site is shown in figure 69. The Super Administrator also sets the acquisition period, after the selection of a KPI. These determinations are obligatory and fixed for all companies. A transformation of KPI values to degrees of performances is made possible through the specification of limits (bad Value and good Value).
5.3.2.4 Product Catalogue

The product catalogue enables the potential consortium partners to offer their potential product contributions in the Virtual Breeding Environment. At the same time, the product catalogue serves as a basis for the iterative generation of a bill of material of an end-product.

The main tasks of this core function are the assignment of product contributions of single companies and their processes, as well as the linkage of all product contributions to other product contributions in the database through the assignment of required supplies. Via the linking of these product contributions with the respectively required supplies, the generation of a bill of material of a given end product down to its needed resources is possible. Initial point for the assignment of required supplies to a product contribution is the list of available product contributions of a company within the Virtual Breeding Environment. This is illustrated in figure 70.

![Figure 70: List entry of a product contribution together with its required supplies.](image-url)
For every single, possible product contribution of a company (produced output), the list shows its name (here: wheel), the deliver-process (here: make-to-order) linked to the product contribution as well as the description (here: tube, casing, rim) of the supplies (required inputs) of this product contribution.

**Unit: Product-components assignment**

There are two lists that are needed for the determination of supplies required for a product contribution. They are illustrated in figure 71.

![Figure 71: Assignment of required supplies to a product contribution and determination of the bill of material of a product contribution.](image)

Supplies can be assigned to the product contribution (e.g. wheel) of a company (Output) already selected supplies for the product contribution „Product A“

Still selectable supplies in the Product catalog
The right list contains those contents of the product catalogue that were already chosen as required supplies for the product contribution to be configured, and the left list shows all other contents of the product catalogue. Only the product contribution that is being configured isn’t available to the user in order to avoid closed loops (screw consists of screw). Besides that, all entries may be selected.

### 5.3.2.5 Additional Functions

Finally, all functionalities that were demand in the requirements definition are met. Nevertheless, yet small supplementations within the framework of Release 1 can increase the operation comfort considerably. In this context, the graphic appearance of the KPI values (Cockpit) is described.

**Cockpit**

The so-called cockpit is the configurable welcome page of the system that offers a graphic overview over the KPI development of one’s own configured KPIs. In other words, the user is provided with a monitoring function that lets him supervise his own KPI developments. The implementation of the monitoring function is divided into two steps. Firstly, all KPIs that shall later be displayed in the *Cockpit* must be selected. So, to allow the selection, the page *Modify Cockpit* generates a list of all configured KPIs of the company. The graphic display itself is extracted from the Image_Graph-package of the PEAR library.

![Figure 72: The cockpit including the monitoring of the KPI development of chosen KPIs and the prompt for mature KPIs](image)
5 Development of an IT-Based System for Prospective Performance Measurement

Figure 72 shows the realization of the Cockpit. The graphical display of the KPI developments is located in the lower area, the prompt for mature KPIs is found in the upper area.

5.3.3 Release 2: Identification and Analysis of possible Consortia

Release 2 contains the bigger share of the application logic and mainly covers the identification and analysis of possible consortia. The analysis is conducted with the aid of the over-all performance of a consortium. The realization of the last five core functions and the introduction of some additional functions are treated below.

The analysis of the performance data that were captured by Release 1 is structured in three phases, corresponding to the method elaborated in section 4.3. The first step is the generation of a product tree for the mapping of the end product’s bill of material. The connections between the administrated possible product contributions (product contribution plus required supplies) which are all filed in the product catalogue are used in the product tree to map the complete bill of material of an end product. Taking the product tree and its available Company Profiles into account, the corresponding process chain is generated in a second step through the linkage of product contributions with SCOR-processes. This process chain is evaluable through the KPI developments that are filed in the Company Profiles and give information about all processes. To obtain a quantitative evaluation, all values of the KPIs are to be aggregated to the over-all performance of a consortium, just like described in section 4.3. Third and last step of the analysis is the graphic display of possible consortia and their over-all performance in a list structure.

The documentation of this release isn’t conducted in units, but it is oriented to the analysis procedure of the Super Administrator. It is possible to do this, because the order of all necessary steps is predetermined.

The Super Administrator enters the analysis function of the system via the menu entry Analysis Network in the navigation menu. The user initially chooses the end product, for which the system is to identify and evaluate possible consortia, from the list Your Products (figure 73 top). The iterative generation of the product tree of the end product to be formed is launched through the confirmation of an end product entry via the button Create. In the process, the system compares (starting with the end product or rather the root of the tree) the required supplies for every product contribution with the database entries of the possible product contributions of every member of the Virtual Breeding Environment and then, in the case of a match, adds a new branch to the tree. A leave and therewith an end of a branch is reached if no further supplies (except raw material) are defined for a product contribution.
The bill of material can now be substituted by a process chain that can be evaluated in its performance through the linking of every product contribution to a deliver process of the SCOR-model.

To complete the selection of the analysis algorithm, the user may set a KPI-filter in the middle part of the analysis page (in the centre of figure 73). Correspondingly to the selection, only the must-KPIs of the chosen perspective are factored in the evaluation of the process chain. This way, either all perspectives or a single selected perspective can be analyzed within the customer-oriented perspectives (Reliability, Responsiveness, Flexibility) and the internal-oriented perspective.

In the lower part of the screen (bottom of Figure 73), the user can determine how many of the most recently captured periods are to be factored in the prediction of the performance and which weight-balancing factors are to be assigned to the individual periods. The planning instrument comes with the possibility to calculate the arithmetic average of all periods, the moving average that implies arithmetically...
increasing weight-balancing factors, and the user-specific definition of the weight-balancing factors with the red bar.

The bill of material of the end product to be produced is used for the display of the analysis result. Here, the consortium that is expected to render the highest performance is shown and if wished also accompanied by the alternatives consortia. An example for the display of the consortium that is calculated to be the best is given below in figure 74.

**Recommended Consortium for: Bicycle (ordered by components)**

**Total Performance: (29,4% ; 45,4%)**

- Show full result tree
- Show recommended result (ordered by supplier)

Component: Gearing
- Delivered by: Partner B.1, Company Indicator: (29,4% ; 30,9%)
- Show details

Component: Wheel
- Performance of Subtree: (46,0% ; 66,3%)
- Delivered by: Partner A.2, Company Indicator: (77,0% ; 63,3%)
- Show details

Component: Tube
- Delivered by: Partner A1.1, Company Indicator: (86,9% ; 55,1%)
- Show details

Component: Casing
- Delivered by: Partner A2.1, Company Indicator: (46,0% ; 80,6%)
- Show details

Component: Rim

**Figure 74: Display of the analysis result: Consortium that is expected to render the highest overall performance**

Figure 75 shows all alternatives in the partner selection for every product contribution of the end product. Correspondingly to the values of the Company Indicator (see section 4.3.4), the alternatives are listed for every position of the bill of material in descending order.
Figure 75: Display of the analysis result: Display of all variants
6 Evaluation

Subject of this chapter is the evaluation of the method that has been developed in this thesis. The method focuses on the prediction of the over-all performance of different variants of a planned consortium. Basis and starting point of the evaluation is a theoretical example case. This example case is deliberately devised to be uncomplex, so the generated analysis results can be understood easily and also verified manually.

At the beginning, the example case is presented (section 6.1). Section 6.2 then shows, which possibilities are provided by the SCOR-model for the analysis of the example case and what can’t be done so far. Thereafter in section 6.3, the consortium planning for the example case is executed using the method that has been developed in this thesis. Finally, the evaluation results are summarized and discussed in section 6.4.

6.1 Presentation of an Example Case

Given is a Virtual Breeding Environment with all in all 20 business members. The end product *product* must be realized for the fulfillment of the current contract. Company *Lead-Company* has direct contact to the customer for at least the length of this consortium. So, *Lead-Company* has to identify the most suitable consortium for the realization of the end product.

![Bill of material of the end product to be realized](image)

Figure 76: Bill of material of the end product to be realized
The bill of material (illustrated above) of the end product is derived from all possible product contributions of the members of the Virtual Breeding Environment.

This bill of material is necessary for the identification of all basically possible consortium partners within the Virtual Breeding Environment. It turns out that 14 companies in the Virtual Breeding Environment could offer product contributions for the realization of the end product and are therefore potential consortium partners. Because of the mastermind position of the Lead-Partner (*Lead-Company*), this Virtual Organizations is a hierarchic network. This network of possible partnerships regarding the contract is shown in figure 77.

![Figure 77: Virtual Breeding Environment of possible partnerships regarding the realization of product (adapted from Thoben 2001, p. 425)](image)

There are time-series of performance for each one of the potential consortium partners, consisting of a homogeneous set of SCOR-KPIs that reach back ten periods. Definitions of the SCOR-KPIs used within the scope of this example case are found in appendix b, together with the KPI prediction values of all potential consortium partners for the upcoming period.
Taking into account the bill of material of the end product to be realized, figure 78 gives an overview in tabular form over the possible product contributions of the potential consortium partners.

It can be perceived from the overview that the Lead-Partner always has at least two alternatives to choose from for every required product contribution. Also, partner A.2 is a system integrator who can assume the responsibility for the product contribution Component A and wouldn’t need any further supplies.

The best suited consortium (prediction) is now to be identified on the explained basic conditions. Regarding the performance targets, all five performance perspectives are equally treated in the partner analysis and selection.
6.2 Possibilities and Limits of the Performance Analysis of the Example Case in the Application of SCOR-Cards

SCOR suggests the usage of SCOR-cards for the quantification and the analysis of the performance of a company within a supply chain (compare to section 3.4.1). The SCOR-cards work with snap-shots of the performance and don’t capture time series. To exemplify this, figure 79 displays the SCOR-card of the Lead-Partner in conformity with the predicted values that are documented in appendix b (adapted from Paul 2006, p.54).

<table>
<thead>
<tr>
<th>Performance perspectives</th>
<th>SCOR Level 1 KPIs</th>
<th>Predicted value</th>
<th>Median</th>
<th>Best-in-class</th>
<th>Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>Delivery Performance To Commit Date</td>
<td>92%</td>
<td>77%</td>
<td>94%</td>
<td>2%</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>Order fulfillment</td>
<td>2,5 days</td>
<td>5 days</td>
<td>1 days</td>
<td>60%</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Upside Supply Chain Flexibility</td>
<td>75 days</td>
<td>68 days</td>
<td>47 days</td>
<td>37%</td>
</tr>
<tr>
<td>Cost</td>
<td>Cost of goods sold</td>
<td>65%</td>
<td>82%</td>
<td>56%</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>Total Supply Chain Management Cost</td>
<td>6%</td>
<td>12%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>Assets</td>
<td>Inventory Days of Supply</td>
<td>128 days</td>
<td>73 days</td>
<td>30 days</td>
<td>77%</td>
</tr>
<tr>
<td></td>
<td>Cash-to-cash Cycle Time</td>
<td>121 days</td>
<td>84 days</td>
<td>9 days</td>
<td>93%</td>
</tr>
</tbody>
</table>

Figure 79: SCOR-card of the Lead-Partner: *Lead-Company*

The SCOR-card synopsizes the performance of a single company for selected KPIs and relates them to benchmarks that are customary for the particular trade. The original aim of the SCOR-card is to reveal relevant fields of action to a specific company that wants to increase its performance. Also, it helps to document one’s own performance for potential consortium partners. So, for this, performance deficits are listed in the last column of the card. These deficits are always the difference between the predicted value and the best-in-class benchmark. In our example, the most notable deficits are the performance perspectives Assets and Responsiveness. In the following, the applicability of such SCOR-cards as a decision support for collaboration formation in Virtual Organizations is discussed.
SCOR-Cards gestatten keine Analyse gesamter Konsortien SCOR-cards don’t allow an analysis of whole consortia

The deviation of the current performance that is given in percent can be read off the column Deficit by a company. Therefore, the individual performance of a single consortium partner is evaluable, but still, its impact on the overall performance of a consortium can neither be read off the SCOR-cards nor derived from them. Necessary for this would be the SCOR-cards of all consortium partners as a data basis. Unfortunately, the SCOR-model doesn’t provide any suggestions for a standardized synthesis that could lead to the over-all performance of a supply chain. To put it all in a nutshell, SCOR-cards mainly support the company-intern analysis and improvement of the potential consortium contributions of a company. There are no views on the design and planning of a consortium included in the SCOR-model.

SCOR-cards do not factor in the temporal development of the performance

Besides the snap-shot of a performance, first of all the temporal development is very important, for both partner selection as well as the process improvement. The temporal development allows to spot trends and season cycles and makes a prediction of further developments possible. However, SCOR-cards only supply snap-shots of a performance that – in the example cases of the SCC- always refer to the current performance. The SCOR-model doesn’t offer any methods for the analysis and extrapolation of temporal KPI developments. Hence, the model suggested by SCOR doesn’t permit statements about future performance developments.

The column Deficits leads to misinterpretations

The column Deficit leaves much room for misinterpretations, especially against the background of a performance comparison of several alternatives in collaboration formation: So, for example, the deficit of 60% in the perspective Responsiveness compared to the deficit of 37% in the perspective Flexibility could lead to the assumption that there is an urgent call for action regarding the responsiveness of the company. Nevertheless, the comparison of the current performance with the median shows that, despite of the calculated deficit of 60%, the individual performance of the investigated company is still much better than that of most of the other potential alternatives (the Median is 5 days, the value of the investigated company is 2.5 days). In turn, regarding the Flexibility (deficit of 37%), the current value of the investigated company lies way under the average (68 days is the median whereas 75 days is the current performance). The appeal of the investigated company as a potential consortium partner is far less influenced by his supposedly high responsiveness deficit than by a low flexibility. This misinterpretation
through the deficit’s reference to best-in-class benchmark can lead to the wrong decisions in partner selection if the performance perspectives are prioritized differently.

- There is no possibility to prioritize the performance perspectives

It was described that the performance perspectives may have different priorities for the strategic alignment of a Virtual Organization and the ideal fulfillment of a contract. Even if the SCOR-cards do synopsize the performance analysis, decisions regarding the suitability of single consortium partners can hardly be derived from them. Frankly speaking, it is rather difficult to compare two different performance profiles without having prioritized the perspectives.

So, from a single company’s point of view, the SCOR-cards are therewith only partly qualified for the analysis of the performance regarding its own potential consortium contribution, as well as for the identification of room of improvement. Insights on the effect of the selection of a consortium partner on the over-all performance of the consortium are no product of the SCOR-card. Indeed, it may be feasible to execute direct comparisons of two potential consortium partners, but the analysis of complex contractor consortia isn’t possible with the analysis methods of the SCOR-model today.

### 6.3 Consortium Planning through Prediction of the over-all Performance of Possible Consortia

In this section, it is shown how the performance analysis results (section 6.2) that are generated by SCOR for single companies is supplemented with the planning instrument developed in this thesis and then used in collaboration formation. The analysis of the example case is done with the developed software and documented in screen-shots. Basic assumption of the example case is all needed Company Profiles are already filed in the database. All steps taken in line with the evaluation are described from the Lead-Partner’s perspective and they are oriented to the application logic of the software, just as illustrated in figure 80.
**Determination of minimum/ideal values of the KPIs for the calculation of degrees of performance**

Firstly, the Lead-Partner must determine the minimum and the ideal values for all must-KPIs. In accordance with the SCOR-card in section 6.2, the median is set as minimum value and the best-in-class as ideal value. Minimum requirement on the individual performance of a company in the partner selection thusly is the average performance customary in this line of business. The ideal value defined by the best branch-specific performance. Figure 81 shows the determination of the minimum and ideal values in the software with an illustrating screenshot.
Figure 81: Screenshot - determination of the minimum and ideal values of the captured KPIs

On basis of the determined minimum and ideal values, the captured KPI values of all potential consortium partners can now be converted into degrees of performance. Figure 82 contrasts the degree of performance that has been defined in this thesis and the Deficit defined by SCOR using the example of the data of the Lead-Partner. Contrarily to the Deficit-values of the SCOR-cards, the degrees of performance allows to relate an individual performance to the respective benchmark in a realistic proportion: Just like the substandard performance in the perspective Flexibility is revealed by a negative degree of performance, the comparatively good performance in the perspective Responsiveness is also expressed comprehensively. The misinterpretation of the performance that was detected in section 6.2 can therewith be avoided and corrected.
In the next step, filters are to be determined for the five performance perspectives, so as to factor in the characteristics of the contract as well as the strategic alignment of the Virtual Organization, when calculating the Company Indicators. In the example case, it was decided not to prioritize any perspective. So, all five perspectives enter the computation of the Company Indicators. The computation is handled by the software in the background. The following therefore manually reproduces the generation of the Company Indicator on basis of the example case (base data is found in appendix b).
Regarding the customer-oriented performance, the Company Indicator exceeds the average performance value customary in this line of business (the degree of performance is 0%, because of the chosen minimum values) by 39.1%. On the other hand, the internal-oriented performance is slightly below average (-2.9%).

**Generation of the bill of material of the end product for the identification of potential consortium partners**

Following the procedure introduced in section 4.3.1, a data tree of the bill of material of the end product as well as of possible partnerships may be derived from the product contributions of all potential consortium partners. This data tree now serves as the basis for the identification and the analysis of possible consortia. The data tree becomes very large if the system is used for real products and that is why it isn’t visualized by the software. So, instead, the analysis result is edited and clearly represented by a table. Figure 84 shows the manually created data tree for the example case. The data tree uses the bill of material to show all possible consortium partners for every product contribution to the end product.
The actual analysis of the example case happens now and is divided into two steps. Initially, the over-all performance is calculated for all basically possible consortia with help of the data tree and the respective Company Indicators. Then, all variants are ordered by their over-all performance. The variant with the highest over-all performance is marked as preferred suggestion by the software, all others are presented as possible alternatives in form of a table.

**Identification of the consortium that is expected to render the highest performance**

The analysis of the example case through the software yields 40 possible variants in collaboration formation. Figure 85 shows the snapshot of this analysis: The product contributions necessary for the end product are listed alphabetically in the upper part. In the third and the fourth column, it says how many companies of the Virtual Breeding Environment require the respective product contribution as supply (# source-processes), or how many companies offer the respective product contribution (# deliver-processes). In this overview, it’s perceivable what relevancy yet single product contributions have for the Virtual Breeding Environment, and how big the dependencies are, that is how fast and well a consortium partner is substituted in a contingency.
Figure 85: Snapshot- required product contributions and number of possible consortia

The lower part of figure 85 shows the number of possible consortia for the realization of an end product (here: Product).

The over-all performance of all possible consortia is described in the next section. At first, the over-all performance is being manually calculated and therewith examined in an example (see appendix b for the data) that is shown in figure 86.
The over-all performance calculated in the example shows that the performance is much higher than the average performance of companies in comparable businesses. The vector of the industry-wide average performance would be the zero vector, according the definition of minimum and ideal values. Figure 87 shows the consortium that is identified by the software as the consortium that will most likely be the best suited consortium for the example case.
Recommended Consortium for: Product (ordered by components)
Total Performance: (29,4% ; 45,4%)

Figure 87: Snapshot- analysis result for the consortium that is expected to be the best suited

Identification of possible alternatives in collaboration formation

Besides the determined suggestion, there is also a table that includes all others alternatives in collaboration formation. The alternatives are listed in figure 88. Thanks to this view, contingency positions within the Virtual Breeding Environment can now be identified and evaluated at short notice if -for any reasons- a consortium partner becomes unavailable.
Figure 88: Snapshot- possible alternatives in collaboration formation
6.4 Discussion and Results of the Evaluation

Basically, the SCOR-model can be used to describe the performance of a process chain, may it be intra- or inter-organizational. Nevertheless, procedures for the analysis of performance data like SCOR-cards are usually limited to the individual consortium contribution of a company. Although basically possible, conclusions regarding the over-all performance of a process chain can hardly be drawn from today’s SCOR-based procedures. Besides inadequate methods for the interpretation of single KPI values (Relation of KPI values and benchmarks), the main deficit of the SCOR-procedure are is the lack of approaches to the aggregation and analysis of bulky and comprehensive performance profiles of single companies. SCOR-cards may be used to capture the performance of possible consortium partners regarding differing performance perspectives, but SCOR doesn’t provide any approaches to the comparison of profiles with varying strengths as a basis for decision-making in partner selection. Prioritizations and rules of aggregation would be necessary for the performance perspectives.

In line with the evaluation, it was elaborated how SCOR-results can be used for collaboration formation in Virtual Organizations by the developed method. For this, and also in view of the over-all performance as a consortium, possibilities of aggregation of the KPI perspectives were presented. The differences between the performance perspectives are considered through the introduction of a Performance Vector. Bad values of a single company regarding the internal-oriented performance can be compensated by a good performance of a consortium partner whereas, in the case of customer-oriented perspective, the chain is always as strong as its weakest link. So, as a consequence, the bigger the consortium, the smaller the influence of a single consortium partner on the over-all performance. This is why, looking at the internal-oriented over-all performance, big consortia are more robust against performance fluctuations of single consortium partners than small ones. In contrast, in the case of the customer-oriented over-all performance, it is other way around. Here, the over-all performance is set by the company with the worst performance. Big consortia thusly react more sensitively to performance fluctuations of the partners than small consortia, because from statistics we know that along with the size of the consortia also grows the number of processes that could be frail.

Concluding, it has to be emphasized that in industrial practice it isn’t a matter of course to create the best possible consortium for a contract through a methodical procedure in partner selection. Often, alternatives aren’t considered because of a lack of methods and tools and a high complexity of products and possible partnerships. Therefore, mainly already existing business relations are maintained and cultivated. So, in the first place, the developed IT-system offers the opportunity to check existing business relations and receive suggestions for alternatives in partner selection.
7 Conclusion and Outlook

A method for the prospective Performance Measurement was developed within the scope of this thesis in order to support collaboration formation in Virtual Organizations. Also, the implementation of the method in a software was described. The methodical procedure in the configuration of a consortium was highlighted as an important aspect in the planning of a Virtual Organization. It was described that the prospective evaluation of the over-all performance of a consortium and the knowledge of possible contingency positions through an appraisal of available alternatives in the partner selection are crucial to the Virtual Organization’s permanent capacity to act. This is important, because the success of a Virtual Organization is mainly to be measured by how permanent the Virtual Organization’s capacity to bargain and deliver can be maintained, particularly in complex networks. At the latest in the event of plan variances like a consortium partner’s temporal incapability to deliver, the knowledge and evaluability of these alternatives within the Virtual Breeding Environment becomes crucial for the success of a consortium. Even big concerns like Airbus are affected by these facts. For example, the A380 consortium was temporally incapable of delivering due to missing alternatives regarding a few but central product contributions (Flugpost 2006). The short-term consequence of the lacking ability to evaluate and instance available alternatives was the massive cancellation of orders (n-tv 2006). This ability becomes a question of survival for Virtual Organizations, because their success mainly depends on the integration of adequate processes of many partners. Now, thanks to the method that was developed in this dissertation, there is a tool that can identify and evaluate alternatives yet in the course of collaboration formation.

The requirements of an accurately specified bill of material usually serve as a basis for the collaboration formation. End product and the criteria for the identification of adequate consortium partners are therefore already determined and the partner selection is now solely carried out on basis of a performance comparison. The method that was developed in this thesis shows how the collaboration formation process can be organized even before a definite bill of material is available. At first, possible product contributions are collected for the generation of a bill of material of the end product, which is done through the inclusion of all potential product contributions of the Virtual Breeding Environment. This pool of possible product contributions may also bring forth constructive alternatives regarding the concrete detail planning of the end product and possible variations on the end product in the context of collaboration formation. The integration of the individual competencies of the potential consortium partners in consortium planning is especially important in the realization of capital-intensive investments (usually unique goods) in order to allow the development of innovative products. The possible product
contributions of a company to the end product are important for the partner selection, just like the performance data.

Precondition for the applicability of the method in a Virtual Organization is the comparability of the potential consortium contributions of all members of a Virtual Breeding Environment. To meet this precondition, the process description of all members must follow the same system and be evaluated with the same KPIs. Only this way, a reasonable inter-organizational aggregation and analysis of the performance data is possible. The developed software is based on the utilization of the SCOR-model that basically fulfills all requirements. At the same time, there is a product reference in the processes of the SCOR-model, so the bill of material can be converted into a process chain. The bill of material of an end product serves as basis for the process chain creation and therewith also for the collaboration formation itself. It’s principally possible to modify, supplement, complete or even substitute the model and the KPI-definitions within the framework of the developed method. In doing so, one has to remember that the model allows a linkage of inter-organizational processes with the bill of material of an end product. The SCOR-model contains all processes for the acquisition, production, and delivery of physical products. Development processes or service rendering networks can’t be modeled the same way. Nevertheless, there are already approaches that could easily be implemented in the software. The VRM (Value Reference Model) should be mentioned in this context.

In addition to the described scope of services and operations of both method and software, many other fields of application are conceivable: Beyond the configuration of networks, also auctions for service offerings and service searches would be possible. Searches and offerings could be filed in the product catalogue and then be used in the sense of a broker; the system could create contacts between potential partners on the basis of stored information. The acquisition of new partners for the Virtual Breeding Environment and therewith the strategic development of its profile of competencies could be supported. Furthermore, the performance data can be used for an internal and an external benchmarking in the future. Horizontal collaborations within the Virtual Organization could initiate common process improvements for the purpose of reaching an excellent range of services as a Virtual Breeding Environment through exchange and comparison of their performance data. The maintenance of the IT-system shall be listed as the last point. Regarding the technical aspects, hosting and maintenance of the software may be outsourced thanks to the web-architecture of the software. Given that both the data security and data protection issues are solved, the developed method could also be offered by consulting companies as external service. The Virtual Organization could then even operate without a web server. Besides the support regarding system maintenance and updating, external service providers could also set up their own service net-
work beyond coaching already existing Virtual Organizations. This network would then act as a collaboration forum and therewith offer (mainly small and medium-sized businesses) the opportunity to find and join networks that they will surely benefit from. Qualified suppliers and convenient collaboration partners for the fulfillment of complex contracts could be found much faster. Also, every member of such a service network would profit from the Performance Measurement System, because it can also be used for the evaluation of internal processes. Even the collection and communication of best-practices by external service providers is thinkable.

In the context of potential application areas, it is important to remember that the results of the method are to support the Lead-Partner of a Virtual Organization as a decision-making aid. The results can not substitute human decisions. Entrepreneurial success can neither be guaranteed nor forced by algorithms and IT-technology, although, a) systematic procedures increase the probability of successful decisions, and b), early knowledge and prospective analysis of the available alternatives improve the process stability.

In conclusion, possible obstacle for the application of the developed method are discussed and dealt with. The willingness to make internal performance data available within the Virtual Breeding Environment was declared to be a crucial precondition for the usage of the developed method. This requires a strong mutual trust between collaboration-willing companies. Today, in industrial practice, the handling of such delicate data is strongly regulated and conducted with extra caution. But whenever companies agree on a basic willingness to collaborate in order to serve the markets with common offers, inter-organizational performance evaluations become indispensable. For example, the optimization of isolated areas of single consortium partners isn’t economically tenable if the effect on the consortium isn’t known. The goal of a Virtual Organization must be to achieve the biggest possible improvement of the Over-all Performance, and for this it is definitely necessary to know the performance of both the involved consortium partners and the possible alternatives. The second obstacle for the usage of the realized software is of a technical nature. So far, it was intended to insert the KPI data manually. However, the most common cause why benchmarking projects failed in the past was the enormous effort of a manual data collection (Mertins 1995, p.26). Therefore, an automated data acquisition is required to reach applicability. The approach of this book is being continued and extensions to the IT-system are presently being developed. For example, the joint project Ecolead (www.ecolead.org) focuses on the development of an information broker that automats the data collection. It’s also intended to import data from ERP-databases and query needed data with a SMS-service. This solution is very promising for important data that must be entered by sales representatives in more or less realtime.
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Appendix A

Overview over the requirements

Correspondingly to the Release-oriented development, the requirements are structured in three sections. At first, the architecture-relevant requirements are defined (basic requirements). Thereafter, the requirements for the specification of the releases are listed.

To make references easier, the requirements are numbered. All requirements are labelled by a letter as **Content**, **Function**, **User-interface-** or **Quality**-requirement. A combination of several requirement types is possible.

**Grundanforderungen**

<table>
<thead>
<tr>
<th>FC10</th>
<th>The companies uniformly collect their KPIs on the basis of the KPI and process definitions of the SCOR-model. The tool should instantly analyze all captured KPIs with the help of a previously determined algorithm and through combination and variation of processes. It should also generate and evaluate process chain configurations on the basis of this procedure.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q15</td>
<td>The Tool should be based on a DBMS</td>
</tr>
<tr>
<td>Q20</td>
<td>The tool is meant to be used inter-organizationally, therefore, it should be network-compatible.</td>
</tr>
</tbody>
</table>
## Release 1

### User- and company-administration

| C100 | There is a profile of every single partner of the Virtual Organization. It carries the contact information (postal address, homepage, contact person, company profile, etc.). |
| C105 | There is a separate profile for every user containing personal log-in data (name and password) and contact information (name, function, telephone number, e-mail, etc.) |
| C110 | Every user is assigned to exactly one company, and every company must have at least one registered user. |
| F115 | Every user must log-in the system with a username and a password before he may enter the web-application. |
| U120 | The system starts out with a login-field, which disappears after the successful login. It then is substituted by the user-group-specific navigation menu. |
| U125 | The navigation menu is adapted to the authorization level of the user (user-group-specific). Links to unavailable functions are hidden. |
| FU130 | If a user looses his password, he may use a modified login-field (only name) to request a new password. The link “Lost your password?” leads to the described login-window. |
| FU135 | The link Registration takes the unregistered users to a registration form. Contact information of the company as well as Company-Administrator may be entered here. The new profile becomes active as soon as a Super-Administrator has checked and approved the registration data. |
| FU140 | The user can exit the application via the link Logout. Anyways, the user is automatically logged-out after a determined time span of inactivity |
| FU145 | The Company-Administrator accesses the user-administration via the menu entry User Management. There, a list of all users of the company is shown. |
| FU150 | A Company-Administrator can create, delete or modify user profiles, as long as they are assigned to his company. The modification of login-name and password are generally not possible. |
| FU155 | Every user may change the details of his user profile. This can be done with a form reached over the link *My Profile*. |
| FU160 | A Super-Administrator enters the company-administration with the help of the menu entry *Network Member*. Heart of the company-administration is a list of all registered companies. |
| FU165 | The Super-Administrator can create, delete and modify company-profiles, and he may also change the e-mail addresses of the users of a company. Even the Super-Administrator is not authorized to make further changes. |
| FU170 | Every Administrator can edit the profile of his company (name, address homepage, further contact details). The form is hidden behind the link *Company Profile*. |

**Process reference model**

| FU200 | A visualization of the SCOR-model is embedded in order to support the navigation within the model (consecutively: Process navigation). After the selection of a process category or a process element, all defined SCOR-KPIs for the selected unit are listed in a table. The KPIs are structured by their perspectives and ordered alphabetically. |
| F205 | The implemented SCOR-model should be editable, at least regarding its KPI-definitions, in order to keep it up to date. |

**KPI-acquisition and acquisition configuration**

<p>| C300 | The values of the last ten periods should be saved for every KPI and every company, so as to document the KPI developments and catch tendencies and developments that may emerge. |
| FCU305 | The link <em>Configure Model</em> brings the Administrator to the configuration page of the company-specific SCOR-model. Here, the SCOR-model is configured and adapted through the selection of single processes and the assignment of KPIs for the evaluation. Process categories can be deleted or added via the two selection-lists, from which the categories to be changed must be selected and confirmed (<em>Submit-Button</em>). In KPI configuration, the acquisition interval/period (weekly, monthly, quarterly and yearly) and the dimension (unit) of the KPIs must be defined by the us- |</p>
<table>
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<th></th>
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</thead>
<tbody>
<tr>
<td>FC310</td>
<td>The administrator may set the first acquisition date in the configuration, so as to collect values of past periods ex post.</td>
</tr>
<tr>
<td>F315</td>
<td>If a KPI is deleted from the process configuration of a company, it also disappears from the KPI-overview (Cockpit) of the employees.</td>
</tr>
<tr>
<td>F320</td>
<td>One of the cockpit’s functions is to draw the user’s attention to mature data inputs. The mature data inputs are shown in a table that can be ordered by either processes or maturity dates. The user can insert data into the table with the help of a form or he can read the details of a KPI by clicking on the KPI of interest.</td>
</tr>
<tr>
<td>F325</td>
<td>The menu entry <em>Browse Metrics</em> lets the user view the company-specific SCOR-model-configuration as well as the inserted KPI-values. For this, the system provides the process navigation element, which, at least in this context, exclusively contains those process categories that were configured for the company. The table of KPIs can also be narrowed down to single perspectives. Furthermore, the user has the option to call up bar diagrams of the KPI values below the table via yes/no-radio-buttons.</td>
</tr>
<tr>
<td>F330</td>
<td>Besides the free navigation through the SCOR processes, the user can also search for specific KPIs. Following the link <em>Search Metrics</em>, a prompt appears asking for search term and further criteria like the limitation of the search to 1) a particular field such as “Name” or “Definition”, 2) the processes that were configured for the company, or 3) the underlying perspective. The Submit-button starts the search and its results are tabulated below the insert form. The column Process is filled with process categories and elements, each one linked to their respective KPI. Clicking on the link transports the user to the corresponding KPI-entry on the <em>Browse Metrics</em> page.</td>
</tr>
<tr>
<td>FC335</td>
<td>In order to allow an inter-organizational comparison of processes, the Super-Administrator should determine must-KPIs that have to be captured by every single company. An evaluation of the KPI values is then possible through the definition of worst and best values.</td>
</tr>
</tbody>
</table>
## Product catalogue and configuration

| C400 | One of the features of the tool is a product catalogue that lists all products produced by the members of the virtual company. |
| FU405 | The Menu link *My Products* leads the Company-Administrators to the product administration. There, all products (outputs) of his company are itemized. |
| FU410 | In the product administration, a Company-Administrator can adopt existing product entries for his own company. This way, the tool can manage several suppliers for one product. |
| FU415 | The Company-Administrator can edit or delete products of his company. |
| FU420 | He may also insert new product entries into the product administration. |
| FU425 | A Company-Administrator may assign required components (required inputs) from the product catalogue to his products. This is how the administered products are connected to bring forth the bill of material. |
| C430 | Every product of a company is connected with exactly one deliver process of the SCOR-model. This causes the interrelation of the bill of material of a product and its corresponding process chain. |

### Additional functions

| F500 | In the cockpit, the captured KPI-values are visualized in form of bar diagrams so as to support the supervision of the process performance. If the user clicks on the graphic, all underlying values are presented for manual revision. |
| F505 | On the cockpit configuration page reached via the menu entry *Modify Cockpit*, the user can add KPIs that have been configured for his company to the KPI display (compare to F500) and delete used ones. |
| F510 | The link *Reference* contains a complete process navigation element of the SCOR-model. By clicking on process categories and elements, the definitions of the selected objects and their individual KPIs are shown. |
F515 | The users of a company can send each other messages in form of emails.

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Release 2

Generation of a process chain and interpretation

| FCU600 | The Super-Administrator accesses the analysis page via the link *Analysis Network*. There, he can calculate the ideal process chain variant for the products of the product catalogue. |
| FC605 | The Process chain variants are found out with the help of a product tree that is generated on the basis of the bill of material of the respective product. |
| U610 | The product structure should be displayed as product tree and bill of material. The process chain may be additionally displayed. |
| FU615 | The display of the process chain variants calculated to be the best should be sortable. Criteria of order are the bill of material and the partners involved in the process chain. |
| FU620 | The algorithm for the evaluation of the processes should be adaptable and in accordance with the procedure developed in the method. |

Additional functions

| FU700 | Using the menu link *HighSCOR*, the Super-Administrator can view the companies with the currently best and/or worst values regarding any KPI. |
## Appendix B

### Definition of the utilized SCOR-KPIs in accordance with Version 8.0 of the SCOR-model (Supply Chain Council 2006).

<table>
<thead>
<tr>
<th>KPI</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash-to-cash Cycle Time</td>
<td>The time it takes for an investment made to flow back into a company after it has been spent for raw materials. For services, this represents the time from the point where a company pays for the resources consumed in the performance of a service to the time that the company received payment from the customer for those services.</td>
</tr>
<tr>
<td>Cost of goods sold (COGS)</td>
<td>The cost associated with buying raw materials and producing finished goods. This cost includes direct costs (labor, materials) and indirect costs (overhead). Note - Cost of Raw Material and Make Costs are generally accounted for in COGS. It is recognized that there is likely to be overlap/redundancy between supply chain management costs and COGS.</td>
</tr>
<tr>
<td>Delivery Performance To Commit Date</td>
<td>The percentage of orders that are fulfilled on the customer's originally scheduled or committed date.</td>
</tr>
<tr>
<td>Inventory Days of Supply</td>
<td>The amount of inventory (stock) expressed in days of sales. The [5 point rolling average of gross value of inventory at standard cost] / [annual cost of goods sold (COGS) / 365]. <strong>Example:</strong> If 2 items a day are sold and 20 items are held in inventory, this represents 10 days’ (20/2) sales in inventory. (Other names: Days cost-of-sales in inventory, Days' sales in inventory).</td>
</tr>
<tr>
<td>Order fulfillment Lead time</td>
<td>The average actual cycle time consistently achieved to fulfill customer orders. For each individual order, this cycle time starts from the order receipt and ends with customer acceptance of the order.</td>
</tr>
<tr>
<td>Upside Supply Chain Flexibility</td>
<td>The number of days required to achieve an unplanned sustainable 20% increase in quantities delivered.</td>
</tr>
<tr>
<td></td>
<td><strong>Note</strong> - 20% is a number provided for benchmarking purposes. For some industries and some organizations 20% may be in some cases unobtainable or in others too conservative.</td>
</tr>
<tr>
<td></td>
<td><strong>Note</strong> - Component metrics (Upside Source Flexibility, Upside Make Flexibility, etc) can be improved in parallel and as a result, this calculation requires the result to be the least amount of time to achieve the desired result.</td>
</tr>
<tr>
<td>Total Supply Chain Management Cost</td>
<td>The sum of the costs associated with the SCOR Level 2 processes to Plan, Source, Deliver, and Return. Note - Cost of Raw Material and Make Costs are generally accounted for in COGS. It is recognized that there is likely to be overlap/redundancy between supply chain management costs and COGS.</td>
</tr>
</tbody>
</table>
## Predicted KPI values of the upcoming period of potential consortium partners

<table>
<thead>
<tr>
<th>Customer-oriented perspectives</th>
<th>Internal-oriented perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>Cost</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>Total Supply Chain Cost</td>
</tr>
<tr>
<td>Delivery Performance</td>
<td>Inventory Days of Supply</td>
</tr>
<tr>
<td>To Commit Date</td>
<td>Cash-to-cash Cycle Time</td>
</tr>
<tr>
<td>Order fulfillment</td>
<td></td>
</tr>
<tr>
<td>Lead time</td>
<td></td>
</tr>
<tr>
<td>Upside Supply Chain</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Reliability</th>
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<th>Lead time</th>
<th>Upside Supply Chain</th>
<th>Flexibility</th>
<th>Cost</th>
<th>Total Supply Chain Cost</th>
<th>Inventory Days of Supply</th>
<th>Cash-to-cash Cycle Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead-Company</td>
<td>92%</td>
<td>2,5 days</td>
<td>75 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>65%</td>
<td>6%</td>
<td>128 days</td>
<td>121 days</td>
</tr>
<tr>
<td>Partner A.1</td>
<td>90%</td>
<td>1 days</td>
<td>52 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60%</td>
<td>8%</td>
<td>111 days</td>
<td>22 days</td>
</tr>
<tr>
<td>Partner A.2</td>
<td>77%</td>
<td>3 days</td>
<td>60 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>67%</td>
<td>9%</td>
<td>80 days</td>
<td>60 days</td>
</tr>
<tr>
<td>Partner B.1</td>
<td>93%</td>
<td>2 days</td>
<td>55 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>62%</td>
<td>9%</td>
<td>41 days</td>
<td>45 days</td>
</tr>
<tr>
<td>Partner B.2</td>
<td>89%</td>
<td>2,5 days</td>
<td>71 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>59%</td>
<td>12%</td>
<td>57 days</td>
<td>112 days</td>
</tr>
<tr>
<td>Partner A1.1</td>
<td>78%</td>
<td>2,5 days</td>
<td>80 days</td>
<td></td>
<td></td>
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<td></td>
<td>68%</td>
<td>7%</td>
<td>71 days</td>
<td>99 days</td>
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<td>Partner A1.2</td>
<td>80%</td>
<td>4 days</td>
<td>58 days</td>
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<td></td>
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<td></td>
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<td>8%</td>
<td>57 days</td>
<td>76 days</td>
</tr>
<tr>
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<td>76%</td>
<td>3,5 days</td>
<td>61 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80%</td>
<td>14%</td>
<td>71 days</td>
<td>80 days</td>
</tr>
<tr>
<td>Partner A2.2</td>
<td>81%</td>
<td>3 days</td>
<td>69 days</td>
<td></td>
<td></td>
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<td></td>
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<td>67%</td>
<td>12%</td>
<td>67 days</td>
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</tr>
<tr>
<td>Partner A.3</td>
<td>45%</td>
<td>5 days</td>
<td>67 days</td>
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<td>20 days</td>
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<td>87%</td>
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<td>84%</td>
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</tr>
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<td>67 days</td>
<td></td>
<td></td>
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<td></td>
<td>61%</td>
<td>7%</td>
<td>41 days</td>
<td>21 days</td>
</tr>
<tr>
<td>Partner B2.1</td>
<td>93%</td>
<td>1 days</td>
<td>54 days</td>
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<td>65%</td>
<td>9%</td>
<td>49 days</td>
<td>47 days</td>
</tr>
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<td>Partner B2.2</td>
<td>90%</td>
<td>1,5 days</td>
<td>50 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>58%</td>
<td>11%</td>
<td>54 days</td>
<td>56 days</td>
</tr>
</tbody>
</table>