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On inter-organizational trust engineering in networked collaborations : modeling and management of rational trust

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Chapter 1

Introduction and research problem analysis

This chapter introduces the problem area addressed in the thesis and presents the domain in which the subsequent research results are applied. It presents the research challenges at high-level and briefly introduces the proposed solution for each challenge. It then addresses the discipline of collaborative networks, which constitutes the domain in which our research results are applied. The chapter further analyzes various background definitions and base concepts of trust and discusses three application example cases which are applied to describe the research motivation as well as problem area addressed in this thesis. Therefore, the chapter presents the problem description, research objectives, the motivating research questions, the scope and the applied methodology to this research. Finally, the chapter introduces the project ECOLEAD in which this research was conducted.

1.1 Introduction

Change has been a keyword in recent decades. Organizations increasingly find themselves in new, more challenging and dynamic environments. In relation to business areas, technology and its practical application change quite frequently. Technological developments and breakthroughs have given rise to varying productivity rates, customer demands, market conditions, standards of living, and so forth.

Faced with (1) ever-fluctuating internal and external demands, (2) continuous changes in operating environments, and (3) changes in facilitating technologies, current organizations and in particular *Small and Medium Enterprises* (SMEs) are forced more than ever to reconsider the way in which they structure, coordinate and handle their businesses and all related processes [Vreed, 1995]. Even the survival of SMEs in the current turbulent market is continuously at risk and has become uncertain. Furthermore, increasing market competitions, current governments' tendencies towards trade liberalization and globalization, scarce resources and changes in customers' demands, volatile business opportunities are among the key factors catalyzing this uncertainty, especially for SMEs [Jones, et al., 2000]. Therefore, organizations and SMEs in particular, are increasingly less able to acquire and respond to business opportunities individually and the traditional point-to-point connections between organizations are being rapidly replaced by participation in cooperation networks.

Among the aborning cooperation networks, one type that is gaining momentum at a fast rate both in business and in research is the so-called *collaborative networked organization* (CNOs). A CNO, as further described in Section 1.2, may include partners (individuals or organizations) that are geographically separated and potentially unknown to each other in advance. One form of CNO is the short-term goal-oriented networks (e.g. virtual organizations

– VOs). A challenge for short-term goal-oriented CNOs is that they must be established dynamically and fluently so as to address a targeted goal, such as to compete in acquisition of and response to volatile business opportunities. Furthermore, in order to efficiently collaborate in such networks, participating organizations need to share a common infrastructure, to effectively exchange information and to share their resources and capabilities in order to, for instance, co-design and co-develop towards the aim of the collaboration. These requirements justify the need for the pre-existence of long-term CNOs, as these provide the necessary base conditions for the dynamic creation of VOs, e.g. the pre-existence of strategic alliances called Virtual organizations Breeding Environments - VBEs.

One key challenge related to both the establishment and operation of CNOs, and in particular to short-term goal-oriented CNOs, is the identification and selection of trustworthy partners for the purpose of collaboration and with the aim of fulfilling business opportunities. As further discussed in Sections 1.2.4 and 1.4, this thesis proposes several innovative solutions to the research challenges that relate to the identification of trustworthy organizations for collaboration, and thus also addresses the challenges that relate to the realization of inter-organizational trust. The main challenges that have been addressed are grouped into the following four categories:

- ✦ Characterization of trust and trust relationships in Chapter 2.
- ✦ Analysis of concepts and aspects of inter-organizational trust, as addressed in Chapters 3 and 4.
- ✦ Rational assessment of organizations' level of trust, as addressed in Chapter 5.
- ✦ Development of a VBE trust management (TrustMan) system, as addressed in Chapter 6.

The approaches, mechanisms and services proposed in this thesis address these challenges and are needed to support the realization of trust in organizational collaborations. Systematic steps for establishing trust relationships among organizations are proposed (in Chapter 2). A multi-criteria approach for analyzing inter-organizational trust is proposed, and then used to identify and analyze the trust elements and their inter-relations (in Chapter 3) and to model those elements (in Chapter 4). Using the identified, analyzed and modeled trust elements, a conceptual modeling approach is proposed (in Chapter 5). This approach is based on the mathematical equations developed for formulating mechanisms that support the rational assessment of organizations' level of trust. Based on the above contributions, a model for developing services supporting processes related to the management of inter-organizational trust is proposed (in Chapter 6).

The remainder of this chapter focuses mainly on the presentation and characterization of the research problems. In order to enhance the analysis and presentation of these challenges, we present the domain in which our research results are applied in Section 1.2. In Section 1.3 we present the background to the definition of trust and its base concepts, and in Section 1.4 we present the research motivation of the thesis, further addressing the above key challenges and introducing several examples cases to which this applies. In Section 1.5 we present the main questions addressed by the thesis and the research objectives, namely the contributions achieved. In Section 1.6, we present the research methodology and in Section 1.7 we briefly introduce the ECOLEAD research and development project, within which this research was performed, and its specific areas of focus. In Section 1.8 we present the structure of the thesis and finally, in Section 1.9 we present the conclusion of this chapter.

1.2 Collaborative networked organizations and breeding environments

During the last decade, digital technology has changed the world in profound and exciting ways. Today, organizations communicate and interact instantly with each other, and securely exchange sensitive information - such as those needed for businesses collaborations - without the traditional limitations of time and location. Collaborative networks, such as global supply chains, have enabled industries to manufacture and deliver products to markets with incredible speed and efficiency. Advances in technology, specifically those related to ICT (*Information and Communication Technologies*), have enhanced the mobility and flexibility of organizations by, for example, facilitating collaboration irrespective of geographic and physical location.

As an increasing amount of information, communication, and commerce are now in digital form and are facilitated through continuously advancing ICT, doors are being opened to a new world of connected experiences that link organizations' interests and market operations into a seamless whole that extends across local, regional, national, international, and global markets. An emerging effective approach for organizations to co-work in such evolving and expanding markets, while taking advantage of the advanced ICTs, is through the configuration of CNOs. The following definition of a CNO is adopted in this thesis.

A CNO is an alliance constituting a variety of entities (e.g. organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital, and goals, and that cooperate/collaborate to better achieve common or compatible goals, and whose interactions are supported by the computer network [Camarinha-Matos & Afsarmanesh, 2006].

In observation of the trends over the last decades and in order to enhance their survivability in the market, organizations in general and SMEs in particular are increasingly interested in attracting others for the purpose of cooperation and/or collaboration. Today, more organizations are ready to share the resources, knowledge, and skills they have, which are scarce in the market, as well as their gained profits, in order to be involved in more business opportunities and to be able to share their risks and potential losses. They now realize that acting together can enhance their competitive power and thus improve their chances of acquiring more and better business opportunities. Therefore, organizations no longer consider forcing others out of the market to be an effective sustainable working approach [Afsarmanesh, et al., 2007].

This thesis addresses two specific forms of CNOs in detail, namely one short-term type (i.e. VOs) and one long-term type (i.e. VBEs). VOs represent short-term goal-oriented collaborations between partners, while VBEs represent long-term cooperation. The definitions of a VO and a VBE adopted in this thesis are as follows.

A VO is an association of (legally) independent organizations (VO partners) that come together and share resources and skills to achieve a common goal, such as acquiring and executing a market/society opportunity [Camarinha-Matos & Afsarmanesh, 2006].

A VBE is defined as a "strategic" alliance of organizations (VBE members) and related supporting institutions (e.g. firms providing accounting, training, etc.), adhering to a base long-term cooperation agreement and adopting common operating principles and

infrastructures, with the main goal of increasing both their chances and preparedness of collaboration in potential VOs [Afsarmanesh & Camarinha-Matos, 2005].

As mentioned earlier, VOs are configured within the VBE environments and, therefore, the potential VO partners are selected among the VBE member organizations. As stated earlier, one important aspect during the configuration of a VO is the identification of trustworthy partners that may be invited to join the collaboration. This thesis mainly addresses the analysis of inter-organizational trust in VBEs and in particular with respect to facilitating the formation of VOs.

Organizations interoperate and collaborate within VO and VBE networks while being facilitated by computer networks, in order to achieve certain common or compatible goals, such as the acquisition of and response to larger, better, and more business opportunities. As stated earlier, different kinds of co-working are applied in short-term and long-term CNOs and in order to further describe and distinguish between the cooperation and collaboration concepts related to CNOs, the following definitions are applied in this thesis [Camarinha-Matos & Afsarmanesh, 2008]:

Cooperation, practiced in long-term CNOs, involves not only the exchange of information and alignment of activities, but also the sharing of resources for achieving compatible goals. Cooperation is achieved by the division of some minor labor (not extensive) between participants. However, a common plan exists that in most cases is not defined jointly, but is designed by a single entity (perhaps by the coordinator/administrator of the cooperation alliance), and which requires some low-level of cooperation.

Collaboration that is practiced in short-term CNOs on the other hand is a process in which entities share information, resources and responsibilities in order to jointly plan, implement, and evaluate a series of activities that will help them achieve the common collaboration goal. It implies a group of entities that work intensively together and enhance each other's capabilities. It also implies sharing risks and rewards that, if desired by the group, can also provide outside observers with the impression of a joint identity. Collaboration involves the mutual engagement of participants to solve a problem together, which requires strong trust relationships and thus takes time, effort, and dedication.

Among other challenges, one basic perceived obstacle to cooperation and collaboration within VOs and VBEs respectively is the creation of trust between the parties involved, which constitutes the main subject of this thesis. Unlike other networks, collaboration in VOs is an intentional property that derives from the shared belief that together the VO partners can achieve goals that otherwise cannot be achieved, or that would otherwise involve much higher costs if attempted individually.

The challenge is to enable the organizations involved to trust each other and to take advantage of the technologies that have been provided to facilitate their cooperation. The effectiveness of collaboration between organizations that are configured to respond to business opportunities has been shown to depend on their ability to quickly create trust in and between each other, which in turn facilitates their sharing of information, resources, costs, and so on. [Msanjila & Afsarmanesh, 2007a]. This thesis mainly addresses the analysis of inter-organizational trust within VBEs and in particular with the aim of facilitating the formation of VOs in VBEs. To enhance the presentation of the thesis, therefore, we first address the concept of a VBE in Section 1.2.1.

1.2.1 Virtual organizations Breeding Environment - VBE

The market and society continuously evolve to cope with the complexity of today's connected digital world. Therefore, the preparedness of an organization that is required to facilitate collaborative initiatives must match the evolution of market. It is more difficult to individually achieve the required preparedness for this matching. Other principal aspects of preparedness and configuration of long-term CNOs - such as VBEs - include establishing common operating principles, acquiring an interoperable infrastructure, and creating trust between organizations. When achieved, these aspects of an organization's preparedness enhance the chance of being able to configure more successful VOs quickly and efficiently.

Certain previous studies have assumed that the most suitable partners for establishing a new VO may easily be identified and selected from the open universe of available organizations, for example through the Internet, and merged into the required VO. However, this assumption overlooks a large number of obstacles in this process, among which the following can be mentioned [Afsarmanesh & Camarinha-Matos, 2005].

- ✦ How to learn of the mere existence of potential partners in the open universe and deal with incompatible sources of information.
- ✦ How to acquire basic profile information about organizations, when no common template or standard format exists.
- ✦ How to quickly establish an inter-operable collaboration infrastructure, given the heterogeneity of organizations at multi-levels, and the diversity of their systems.
- ✦ How to build trust between organizations, which is the base for any collaboration.
- ✦ How to develop and agree on the common principles of sharing and working together.
- ✦ How to quickly define the agreements on the roles and responsibilities of each partner in order to reflect the sharing of tasks, the rights on the produced results, and so on.

As a basic rule, supporting the dynamic/fluent formation of collaborative networks, such as in a VO consortium, requires its potential partners to be *ready and prepared to participate* in such a collaboration environment, as addressed in Figure 1.1. The foundation of this readiness should include reaching commonality agreements on aspects such as the interoperable infrastructure, operating rules, and cooperation. Any collaboration also requires that all involved organizations meet the required level of competency and performance to be considered trustworthy by other partners. Therefore, the concept of a VBE has emerged as the necessary context for the effective creation of dynamic virtual organizations.

A main aim of the VBE is focused on the transition from point-to-point connections between organizations to a network structure in order to increase the chances of its member organizations' involvement in opportunities for collaboration, and to reduce the costs and time needed to configure opportunity-oriented VOs (Figure 1.1). To conclude, the transition from point-to-point connection to networked structure enhances organizations' preparedness in the following aspects [Afsarmanesh & Camarinha-Matos, 2007].

- ✦ Maintaining common sharing and operating principles.
- ✦ Acquiring an interoperable infrastructure.
- ✦ Achieving the same level of understanding through common ontology.
- ✦ Defining common value systems and performance metrics.
- ✦ Creating trust between organizations.
- ✦ Acquiring systems for assisting the management of cooperation and collaboration.

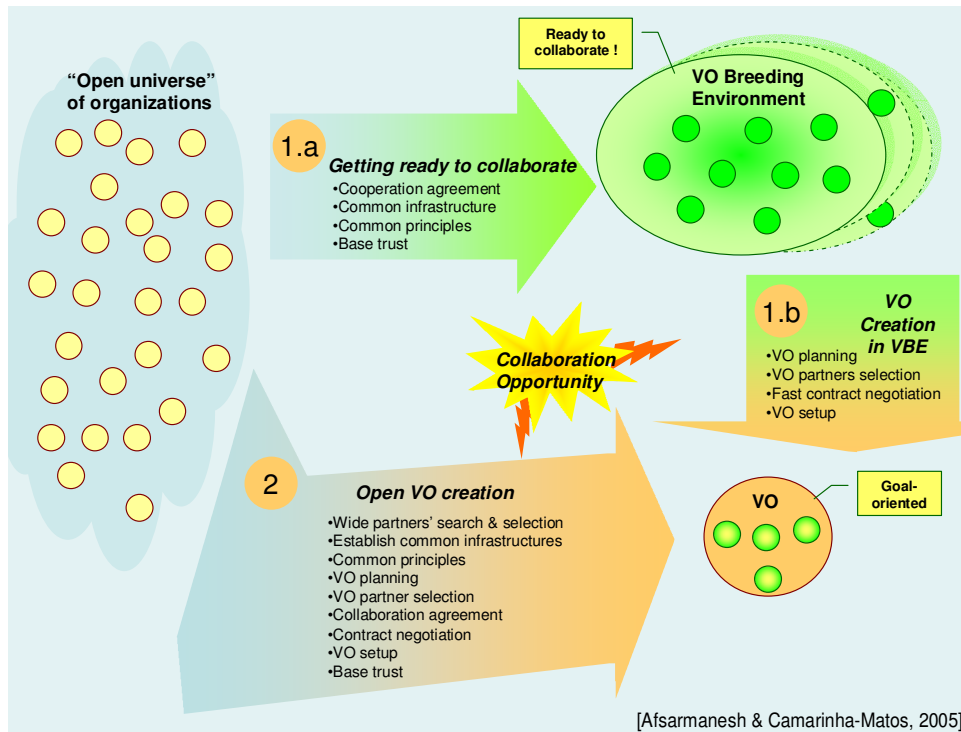


Figure 1.1: The visualization of a VBE concept

This figure shows two possibilities for creating a VO, namely, through the VBE and directly from the open universe. It also shows the role of the VBE in providing chances for organizations to address some preparatory aspects a-priori to the configuration of the VO. In this figure: (1.a) exemplifies the preparedness aspects that are addressed within the VBE a-priori to acquiring an opportunity; (1.b) shows the preparedness aspects that shall be addressed to configure a VO within a VBE after acquiring the opportunity; and (2) exemplifies some aspects that need to be addressed when configuring a VO involving partners from the open universe.

1.2.2 Addressed challenges and gained advantages for organizations joining VBEs

A large number of factors both force and motivate organizations to operate in a very dynamic manner [Geerlings, et al., 2001], what is supported through the VBEs. Influential factors here include continuous advances in ICT infrastructure, dynamic changes in markets and customer demands, increased services quality requested by customers, new political factors such as market globalization and liberalization, and turbulent economic situations. Business-based and politically-based decisions now have to be taken much faster (i.e. needing quick response) in order to seize opportunities that are themselves scarce and volatile, and that require the application of advanced technologies for the support of decisions [Msanjila, et al., 2005]. In addition to the required fast response to emerging opportunities, the volatility of the production markets, such as the *perishable product* market that have been used as examples to define some of the approaches presented in the thesis, has been increasing. In particular, Chapter 5 characterizes the following emerging business requirements and challenges that motivate organizations to join VBEs.

- ✦ **Required competencies:** Production and manufacturing industries must acquire and maintain sufficient, varied, and strong competencies to be able to cope with the current demands that need to be met for each business opportunity. It is becoming ever-more difficult and rare for a single industry to equip itself with the increasing number of competencies that are required for the entire life cycle of production.
- ✦ **Required resources:** Various - and sometimes an immense amount of - resources are needed to produce each kind of product, and in some cases dedicated to a single business opportunity. These resources are not always reusable for other business opportunities, since different customers' requirements change continuously and become more one of a kind. Therefore, acquiring and keeping all required resources has proven expensive and difficult for individual industries.
- ✦ **Required investment:** Business opportunities demand a large start-up investment a priori to their execution. In some cases, the costs incurred during the pre-investment stage may not even be repaid during the execution of the business opportunity, and thus become a part of the fixed costs. In principle, fixed costs do take more time to be repaid; however, since customer requirements are continuously changing there is no guarantee that such investments will be re-used to meet other customers' needs. Cooperation and/or collaboration with other organizations can help to prevent the incurrence of certain unnecessary fixed costs by re-using some of the investments made previously by other organizations.
- ✦ **Short delivery time:** Customers now demand shorter delivery times. They need their products and services to reach the market before their competitors' products do in order to generate more profit, which an enterprise alone can hardly afford.
- ✦ **Change in requirements:** The current market environments are very volatile. Consequently, business requirements change continuously. This further raises the pressure on industries to advance capabilities and to equip themselves with much-needed resources, competencies, and so on.

Once an organization joins the VBE there are a large number of potential benefits that can be gained. These include the following [Afsarmanesh & Camarinha-Matos, 2005]:

- i) *Agility in opportunity-based VO creation:* supporting a reduction in the needed efforts and complexity, flexibility for VO re-configurability, and cost effectiveness.
- ii) *Provision of base effective ICT infrastructures for members:* the common grounds for interoperability, inheritability and collaboration.
- iii) *The VBE bag of assets:* providing properties of interest for its members and general sharable information or knowledge (e.g. standardized product definitions and processes), software tools, lessons learned.
- iv) *Provision of mechanisms, guidelines, and assisting services:* for both motivating and facilitating the configuration and establishment of VOs, and for creating a system of incentives, mechanisms to create positive reputation, and services for partner searches, contract negotiation, etc.
- v) *Proactive management of competencies in VBE:* assuring coverage of the needed competency/resources within the VBE.
- vi) *Assuring continuity support through support institutions:* Supporting insurance, branding, training, etc.
- vii) *Supporting creation of trust among VBE members:* by recording the performance history, and definition of criteria for organizations' trustworthiness.

- viii) *Provision of general guidelines for collaboration*: constituting rules of conducts, working and sharing principles, value systems, collaboration ethics and culture, IPR protection, etc.
- ix) *Enhancing the chance for VO involvement*: through the provision of members' profiles in the VBE catalog, including their competencies, resources, products, services, and so on, and helping member organizations to acquire opportunities.
- x) *Improving the potential / capacity of risks taken by the VO initiators*: due to a reduction in the VO setup efforts/time, and the availability of both a wide variety of competencies (resources) and indicators of the level of trust and past performances of VBE members.

1.2.3 Readiness for joining VBEs

To reduce the severity of the challenges mentioned in Section 1.2.2, most organizations and particularly SMEs in production and service industries increasingly link with other organizations and join in different forms of CNOs. For example, in the perishable products market, as exemplified in Chapter 5 for the analysis of organizations' trust level this trend is observed.

It is clear that every organization needs to go through the preparation/readiness stage in order to join a CNO. However, the preparation stage is much easier for an organization if it joins a long-term *cooperation alliance* in advance (e.g. to become a VBE member), as opposed to if it joins an opportunity-based *collaboration network*, (e.g. to become a VO partner), which involves a more extensive preparation stage that starts from scratch. Facilitating the preparedness of organizations for their participation in VOs is in fact one of the main reasons for establishing a VBE.

In order for an organization to effectively participate in a VBE, at the base of its preparation stage are the adoption of the VBE's common ICT infrastructure and the interoperability approach, which together constitute the minimum base for any cooperation/collaboration network. Furthermore, the main requirements for preparation and adjustment of organizations for the purpose of joining a VBE are reviewed specifically in terms of the following aspects [Msanjila & Afsarmanesh, 2007a]:

- ✦ **Sharing processes**: organizations must be capable of participating in required (business) processes and be prepared to join and inter-link their efforts with each other, while different organizations may exercise different sets of processes, standards and practices, and a different level of autonomy. Depending on the level of cooperation required within a VBE, this requirement can prove to be very challenging and complex.
- ✦ **Sharing resources**: organizations must possess resources that are valuable to a VBE and be willing to share them with others. They must also be capable and willing to use other partners' resources. In addition to willingness, in order for an organization to share, this requirement implies compliance with the common VBE sharing policies, and the need for experience, skill, knowledge, and so on to prepare the sharable objects, and to support this sharing activity. For example, in order to prepare to share a technology-related resource (such as computation facilities), the organization must make sure that the resources comply with some standards in a VBE, such as those relating to communication and interoperability.
- ✦ **Sharing competencies**: it is difficult for an organization to acquire all the competencies that are necessary to assure its existence in business and thus get competitive opportunities. In collaborative networks, there is a chance to share competencies of other organizations and the proper management of these available and emerging competencies

in VBEs is the necessary base element to support this requirement. Organizations must be prepared to offer some of their own competencies for this purpose, as well as benefit from the pool of available competencies in the VBEs. For example, in order to share programming-related competencies, such as re-using each others sharable codes, a certain level of programming knowledge and competencies are required of the employees in an organization (e.g. the availability of scientific programmers, computer science graduates, etc.) and must be demonstrated.

✦ **Coping with contradicting interests, goals, and culture:** each member organization in a VBE has its own internal interests, goals, and culture. Beyond the common interests and goals that have been planned to be achieved together, each organization may wish to achieve some of its own internal interests and goals, which might sometimes contradict those of the other organizations. Organizations must be prepared and expect to collaborate towards the common VBE goals, and to tolerate or adjust to differences that fall beyond it.

✦ **Sharing governance rules and value system:** organizations must comply with the common rules of operation and behavior in a VBE. These rules aim at ensuring that every organization joining the VBE or maintaining its membership in the VBE possesses at least the basic qualifications (such as possessing the required set of competencies, having at least the allowed minimum level of trust, etc.) and also commit itself to a number of aspects related to the operation of the VBE (such as agreeing to the operating and sharing principles, agreeing to the VBE administration principles, rewarding and sanctions policies, etc.). To evaluate whether organizations meet such set of VBE rules, organizations will be required to provide their related information. For example, they must contribute to the information needed for the assessment of their trust level that constitutes a base for their readiness to cooperate/collaborate in a VBE, as well as meet/preserve the base level of trust that is required by the VBE in which they are involved.

1.2.4 VBE management and the need for trust

This section mainly addresses the management of VBEs and its need for inter-organizational trust as the means to facilitate the performance of VBE management-related activities. It first presents the general aspects of traditional organization management in order to distinguish and compare the focus of activities will be performed in the VBE with those of traditional organizations. Furthermore, it presents the general necessary VBE management activities relating to each stage of the VBE life cycle. Finally, it addresses and justifies the fundamental need for establishing inter-organizational trust in VBEs.

In principle, management comprises directing and controlling a group of people or entities (e.g. departments, or organizations) for the purpose of coordinating and harmonizing that group towards accomplishing a common goal (Howe, 2004). In traditional practices, management often encompasses the deployment and manipulation of human resources, financial resources, technological resources, and natural resources in a company. However, it can also refer to the individual or a group of people who perform the act(s) of management. The generic categories of management include (Center, 2008).

- *Organizing:* making optimum use of the existing resources to enable the successful implementation of plans.
- *Controlling/monitoring:* checking progress against plans, which may need plan modification according to feedbacks.

- *Planning*: deciding what needs to be performed in future, e.g. immediately or in weeks, months, years, etc.), and generating plans of action to reach the objectives.
- *Leading/Motivating*: applying mechanisms and strategies to get others into playing an effective part in achieving plans.

The above definitions have been applied successfully to the management of traditional organizations with static structures, such as traditional business companies. These organizations typically practice repetitive and fixed business processes. The following fundamental aspects indicate the static nature of traditional organizational structures:

- ✦ ***Fixed or known resources***: products or services that a traditional organization can offer to its customers are usually well defined and standardized. These products or services can only be customized to meet specific customer requirements, but usually they do not require re-development. Thus, the resources that are needed for manufacturing products or providing services are usually known before a specific opportunity is acquired. These resources can be obtained and kept in an organization a priori to the search for and the acquisition of business opportunities. The management of resources mostly focuses on either ensuring their availability within an organization or on time acquisition whenever is needed.
- ✦ ***Fixed or known competencies***: as stated above, products or services that a traditional organization can offer are usually known and standardized. Thus, the competencies that are required to support the manufacture of products or the provision of services are also known and standardized. The management of such competencies is mainly focused on either enhancing the existing ones (e.g. through specialized training of employee) or acquiring new or qualified employees.
- ✦ ***Static and specific business strategies***: products or services that can be offered by traditional organizations are usually standardized. Therefore, these organizations maintain static or long-term business strategies. These strategies focus on, for example, keeping past customers for as long as possible, or acquiring as many new customers as possible. The management of these processes follows well-defined organizational business strategies.
- ✦ ***Static sharing and operating principles***: most traditional organizations have a culture of sharing achievements (e.g. percentage of yearly profit) with their employees, which may be offered as a motivation benefit (e.g. end of year bonus). The principles used to distribute such benefits are usually known and standard within an organization and depend on aspects such as salary levels, employee positions and employee performances. The management of these activities therefore, follows defined principles within the organization.

On the other hand, unlike the traditional organizational structures, VBES have dynamic structures and the required business processes are unique. For example, the VO creation within a VBE is unique to each configured VO since it responds to a specific opportunity. Among others, the following fundamental aspects indicate the dynamic nature and characteristics of the VBE structures.

- ✦ ***Dynamic resources***: VBES can offer their products or services to their customers only through the configuration of VOs. The resources that are required to manufacture products or provide services belong to VBE's member organizations. Therefore, VOs are uniquely configured constituting "best-fit" organizations that are capable of sharing or exchanging their resources in order to respond to opportunities. The partners may change for every VO that is configured, even if the same product or service has to be provided to a customer. Therefore, the availability of the resources cannot be known or guaranteed a

priori to configuring the VO. The management of such resources in VBEs mostly focuses on ensuring that the resources needed in the current market can be provided by its VBE members.

- ✦ **Changing competencies:** VBE competencies constitute a set of the aggregated competencies of its member organizations. Thus, VBEs do not have competencies of their own beyond those of their members. The management of competencies focuses on ensuring that all of the related competencies that are needed in the market exist within the VBE. One fundamental approach to fill competency gaps is through inviting external organizations to become VBE members and thus provide missing competencies.
- ✦ **Dynamic business strategy:** VBE business strategies need to change depending on the market changes, i.e. with a consideration for the following areas of focus: the acquisition of potential member organizations, support for opportunity brokerage, the facilitation of VO configuration, the provision of information to actors in a VBE for the purpose of making informed decisions, and so forth. In other words, the VBE administration primarily focuses on facilitating the success of some of these processes and subsequently carries out dynamic changes to the VBE's strategy as perceived necessary.
- ✦ **Opportunity-based sharing and operating principles:** the fundamental benefits of operating in a VBE are gained through participation in VOs. Potential VO partners negotiate on how benefits will be shared while operating in the VO and the VBE administration advises/supports such negotiation by providing these with necessary information and negotiating templates.

Considering the differences between the management aspects in traditional organizations and in those of VBEs, as addressed above, it is clear that a VBE administration cannot directly apply the traditional management approaches in handling its activities. In addition to the above differences, the VBE management activities and the focus on every activity may change according to the specific stage of the VBE life cycle. Therefore, a priori to addressing the general VBE management activities, where we demonstrate the need for establishing inter-organizational trust, we first present below the background VBE management activities typically performed in practice by the VBE administrations, during different VBE life cycle stage.

VBE life cycle stages and their related management activities

The management of a VBE may need to perform different activities at different phases of the respective VBE's life cycle. Thus, to enhance the presentation of the basic VBE management processes we first briefly address the VBE's life cycle, which comprises three high level distinct phases as follows.

Each VBE first undergoes the *creation phase*, during which a number of elements are characterized and initiated. This occurs during its two sub-phases, namely the *initiation & recruiting* and the *foundation* (see Figure 1.2). During the initiation & recruiting sub-phase, the VBE administration performs (or supports the performance of) the following main activities: setting up & running the VBE management system and ICT- tools, loading existing ontology & thesaurus, setting up domain parameters & nodes, and so on. During the foundation sub-phase, the VBE administration performs (or supports performing) the following main activities: adapting the VBE ontology, adapting database schema and creating repositories & interfaces for database access, entering administrative data, and registering founding members.

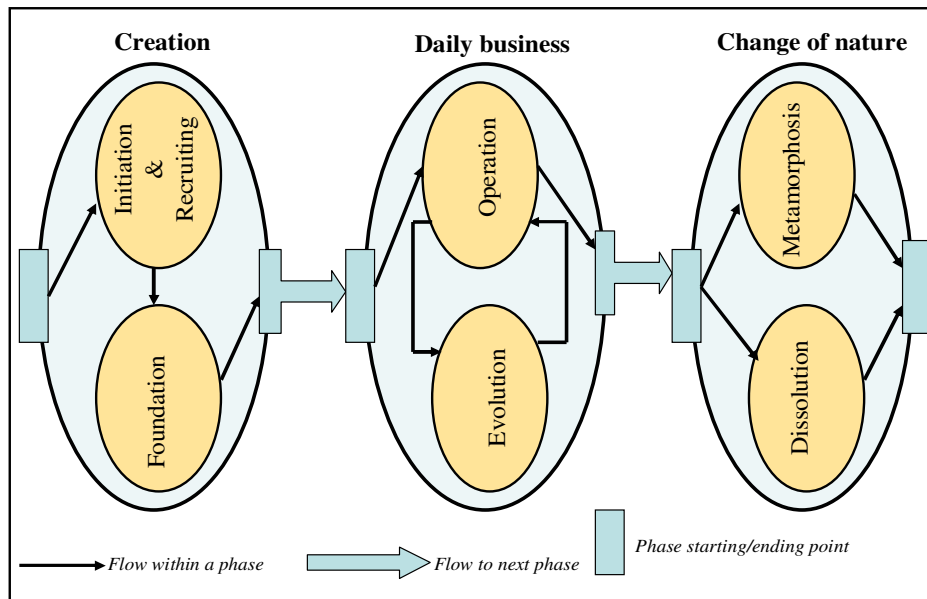


Figure 1.2: Phases of the VBE life cycle

As shown in this figure and explained in this section, the sub-phases occur in certain orders as follows: (i) in the creation stage, sub-phases occur in sequential order, (ii) in the daily business stage, sub-phases occur in concurrent order and (iii) in the change of nature stage only one of the two sub-phases can occur at a time.

Following the *creation phase*, the VBE undergoes the *daily business phase*. This phase has two parallel sub-phases, namely the “*operation*” and the “*evolution*”. This phase constitutes the bulk of the VBE’s life-time and thus it is a relatively much longer than the other two phases. During this phase many collaborative activities, such as repetitive acquisitions of and responses to business opportunities, are performed in the framework of achieving the VBE objectives. During this phase therefore, the main management activities of the VBE administration are aimed at supporting acquisition and supporting such responses to business opportunities. An example of this may include activities related to ensuring that competencies required in the market actually exist within the VBE. Furthermore, during the *operation* sub-phase minor changes become sporadically required, e.g. inviting new member organizations to fill the gaps in competencies discovered in the VBE. In response to such minor changes the VBE undergoes the *evolution* sub-phase. In this phase, the VBE administration performs (or supports performing) the activities that are required to facilitate evolution of the VBE.

The last high-level phase is called the *change of nature*. This phase has two independent, disjoint and parallel sub-phases, namely the *metamorphosis* and the *dissolution*. However, since a VBE is a long-term alliance and considering the valuable bag of assets (including sharable knowledge, resources, etc.) that are gradually collected within the VBE, its *dissolution phase* – the closure of the VBE – is a very unusual situation. Instead, it is much more probable that the VBE goes through the other sub-phase - the *metamorphosis phase* - where it can undergo a major evolution that changes its form and purpose. During the *change of nature* period, the VBE administration is

responsible for ensuring that all the assets are either inherited or transferred to another VBE when metamorphosis occurs or to another specific organization(s) when dissolution occurs. The following section zooms in within the VBE's daily business phase, and addresses four specific VBE management activities that require establishment of inter-organizational trust in the VBEs.

The need for inter-organizational trust in VBEs

As stated earlier, the analysis of inter-organizational trust in VBEs, and in particular for the formulation of VOs within VBE environments, is fundamental for effectiveness of VBEs. Four key processes for the VBE administration that require rationally managed inter-organizational trust in VBEs are discussed below. These include: *VO configuration*, *new membership evaluation & registration*, *opportunity brokerage*, and *decision-making for managing daily activities*.

a) Process 1: VO configuration

Upon the brokerage of an opportunity, the VO planner - which is the organization appointed to configure the VO - selects potential partners among the VBE member organizations to configure the VO. One challenging issue related to the selection of such partners is the analysis of their level of trust, in order to select the "best fitting" set of partners for that specific VO. As observed in practice, VO partners only collaborate effectively when they are assured about the trustworthiness of others. Consequently, the organizations' level of trust must be thoroughly analyzed so as to support the performance of this VBE management process. The main focus of this thesis is establishing an approach that rationally analyzes inter-organizational trust and supports for reasoning on such subsequent results of its analysis.

b) Process 2: new membership evaluation and registration

VBEs are not closed border environments, rather controlled border environments. This implies that any organization wanting to join a VBE may apply for VBE membership. An organization may become a member of a VBE in one of the following two ways:

- ✦ The first case is when an organization realizes that operation within a VBE is more beneficial than operating individually, and thus decides to join. In this case, membership process is initiated by the organization itself and by sending an application to the VBE.
- ✦ The second case is when a VBE administration identifies some gaps, such as in competencies, which need to be filled in order to enhance a VBE's competitiveness in the market and within society, and thus decides to invite external organizations into the VBE. In order to fill such gaps, a VBE may in this case actively search in the market for the most suitable organizations to invite. The process for becoming a member is thus initiated by the VBE by means of an invitation to these organizations.

Irrespective of which approach initiated the membership processes, a VBE administration must preserve a certain level of trust throughout its organizations, which is usually the level at which they are considered to be potential VO partners. Therefore, all membership applicants must meet this level of trust in order to be registered and to remain in the VBE. Organizations invariably possess different characteristics, such as their business focuses, capabilities and past performance records. A rational analysis of trust should capture all such heterogeneous aspects in order to support an examination of the trust level on the one hand and on the other hand to make it possible to reason on the results. This thesis addresses these specific aspects of inter-organizational trust.

c) Process 3: opportunity brokerage

Each VBE operates in a normal market/society that contains competitors, including other VBEs and large strong companies. Customers that either provide the opportunities or identify which providers should acquire those opportunities must trust the respective VBE. Therefore, VBEs should demonstrate their trustworthiness for the purpose of acquiring the opportunities for which they bid. Aspects that customers might prefer to analyze in order to decide on a VBE's trustworthiness may include the "trust level" of the VBE's organizations. This thesis addresses these aspects of inter-organizational trust.

d) Process 4: decision-making for managing daily activities

A number of administrative decisions are made daily in a VBE for the purpose of its effectiveness and smoothing its continuity. Some crucial decisions include, for example, accepting new membership applicants, rewarding or sanctioning member organizations, appointing an organization to take an administrative role (e.g. VO planner) and defining new VBE policies or principles. These decisions are typically made by the VBE administration. Nevertheless, such decisions indirectly affect all VBE's members. Therefore, the organizations making such decisions must be itself be trusted by all participating VBE members. These aspects of inter-organizational trust are addressed further in Section 3.3 of this thesis.

1.3 Background on definition of trust and its emerging base concepts

In this section we define the base concepts related to the rational establishment of trust between organizations. We also present a survey of a number of existing trust definitions in order to provide a comparison with the definition of trust as applied in this thesis.

1.3.1 Diversities among definitions of trust

Trust is a complex subject and is related to many aspects in multi-disciplinary areas. It is addressed, for example, in relation to the security, risks, privacy, belief, honesty, truthfulness, competency, reliability, past history, and so on of the trusted parties. Due to the variations in its interpretation and the variations in its perception by involved parties in both practice and research, the concept of trust is defined differently in various disciplines. There is still no consensus in the literature on what trust means and what constitutes the management of trust between different entities, such as individuals or organizations [Povey, 1999]. However, many researchers have recognized its importance for smoothening interactions and cooperation between both individuals and organizations [Camarinha-Matos & Afsarmanesh, 2006]. The significance of trust in today's collaboration is due to the fact that it is an important factor for enabling interactions and cooperation between both individuals and organizations [Blomqvist, 2005].

The lack of consensus on the definition of trust has led researchers to define trust differently for the purposes of providing a common understanding in their specific domain or application environment. For example, despite the need to standardize the definition of trust for online transactions, different researchers simply use and assume definitions of trust in relation to their specific topic, such as the authentication, security, reliability and availability of the supporting system, or even the ability of the customer to pay for a purchase online by using well known credit cards, etc. In each application area, however, certain researchers have tried to approach and analyze trust in a generic way.

With respect to online transaction technology, Kini and Choobineh [1998] have addressed the theoretical framework of online trust, examining it from the perspective of personality theorists, sociologists, economists, and psychologists. In their work they started by defining trust according to the Webster dictionary as: *an assumed reliance on a person or something. It is a confident dependence on the character, ability, strength, or truth of someone or something. It is a charge / duty imposed in faith / confidence or as a condition of a relationship. Thus it simply means to place confidence in an entity.*

Using this definition, they further highlighted the implication of trust in daily practices and combined this with the results from their analysis of the social psychological aspects of trust, in order to establish a definition of trust in online systems, which proceeded as follows: *“a belief that is influenced by the individual’s opinion about certain critical system features”* [Kini & Choobineh 1998]. Although their analysis and conclusion addresses the general concept of trust in a system, it also focuses on individuals’ trust and specifically in relation to those involved in e-commerce.

The European Commission Joint Research Center defined trust as *“the property of a business relationship such that reliance can be placed on the business partner and the business transactions developed with them”* [Jones, et al., 2000]. This view of trust is based on the area of business management and provides an interesting analysis of what must be done to enable and enhance trust between partners in business. In the analysis related to her work, Jones [Jones et al., 2000] stated that the following aspects of trust are fundamental for partners in business:

- ✦ The identification and reliability of business partners.
- ✦ The confidentiality of sensitive information.
- ✦ The integrity of valuable information.
- ✦ The prevention of unauthorized copying and use of information.
- ✦ The guaranteed quality of products and services.
- ✦ The availability of critical information.
- ✦ The management of risks relating to critical information.
- ✦ The dependability of computer services and systems (the availability, reliability, and integrity of infrastructure; the guaranteed level of services; and the management of risks relating to critical infrastructure).

The Oxford Dictionary defines trust as *the firm belief in the reliability, truth or strength of an entity*. In this definition, a trustworthy entity is basically highly reliable and so will not fail during the course of an interaction; will provide a service or perform an action within a reasonable period of time; will tell the truth and remain honest with respect to interactions; and will not disclose confidential information.

In view of these varied definitions, trust can be regarded as a composition of many different attributes: reliability, dependability, honesty, truthfulness, security, competency, past history of individuals, timelines, and so forth. Any of these may be considered, depending on the environment and application for which the trust is being specified.

In spite of the attempts to define trust in research and the difficulty to reach consensus among researchers, the word “trust” in relation to inter-personal trust in particular and as used daily by individuals refers to one person’s opinion of another person.. Not only is an estimation of another’s intention needed to establish inter-personal trust relationships, but also an estimation of others’ potential competencies. Gambetta [Gambetta, 1988] provided a definition of individuals’ trust and this definition is widely used: *...the subjective probability*

by which an individual “A” expects another individual “B” to perform a given action on which A’s welfare depends. Furthermore, the three following definitions dominate current research into the trust in different entities:

- ✦ *Trust is the willingness of a trustor to be vulnerable to the actions of another party based on the expectations that the trustee will perform a particular action important to the trustor irrespective of the ability to monitor or control the trustee [Mayer, et al., 1995].*
- ✦ *Trust is the belief in the competency of an entity to act dependably, securely and reliably within a specified context [Grandison & Sloman, 2000].*
- ✦ *Trust is a psychological condition comprising the trustor’s intention to accept vulnerability based upon positive expectation of trustee’s intentions and behavior [Rousseau, et al., 1998].*

The diversity between the existing definitions and the differences among their identified elements make it challenging for us to properly characterize trust as it needs to be addressed today. As we pointed out previously, there are many theories on trust, some of which diverge only in their identification of the grounds on which they are based [Settle, 1998]. Despite the difficulties in solidifying the definition of trust, the concept of trust is applied daily in practice as a base for cooperation and collaboration between both individuals and organizations. Past research on VBEs reports that the effectiveness of the establishment of trust and the effectiveness of VO creation depend on the balance of organizations’ level of trust [Mezgar, 2006].

As addressed further in Chapters 2 and 3, trust relationships in VBE environments must be addressed from three specific points of view, namely those of *the VBE member organizations, the external stakeholder organizations, and the VBE administration organization*. Therefore, while this work can benefit from general past research on trust relationships between individuals, the results of such research cannot be directly applied. Trust between organizations in VBEs is a more complex subject, which must be addressed in relation to the interdisciplinary between the domains and the heterogeneities and contradictions between the interests and the goals of organizations involved [Msanjila & Afsarmanesh, 2007a]. In our research, the *identification and tuning of trust elements, modeling of trust and trust elements, assessment of trust level, and the establishment and promotion of trust relationship* constitute the main focus of the management of trust among organizations in VBEs [Msanjila & Afsarmanesh, 2007d]. The following definition of trust between two organizations is applied in this work:

Trust between two organizations, as it is applied in VBEs, is the objective-specific confidence of a trustor organization to a trustee organization based on the results of rational (fact-based) assessment of the trustee organization’s level of trust [Msanjila & Afsarmanesh, 2007c].

Therefore, a rational (fact-based) trust creation refers to the process of creating trust between organizations using the results of a rational (fact-based) assessment of their level of trust. Only measurable elements (numeric data) are used for such an assessment and the resulting trust levels can be supported with formal reasoning (i.e. mathematical equations) that is used during the rational assessment of level of trust, which in turn supports reasoning about results [Msanjila & Afsarmanesh, 2007a].

1.3.2 Base concepts of trust

As described in Section 1.3.1, the concepts of trust are interpreted and perceived differently. Consequently, these differences affect the understandability of the base concepts of inter-organizational trust in research and practice. In this thesis we use the following definitions of base concepts of trust parameters for organizations [Msanjila & Afsarmanesh, 2007a].

- ✦ **Trust actors:** refer to the two parties involved in a specific trust relationship. The first party is the organization that needs to assess the trustworthiness of another, and is referred to as the trustor. The second party is the organization that needs to be trusted and which will thus have its level of trust assessed; and it is referred to as the trustee.
- ✦ **Trust level:** refers to the level of intensity of trust for a trustee organization in a trust relationship, based on an assessment of the values for a set of necessary trust criteria. Clearly enough, the criteria for assessment of organizations' level of trust vary and have a wide spectrum, depending on the specific purpose (e.g. the requirements, the perspective, and the objective of the establishment of trust). When the level of trust is assessed for a specific purpose - such as inviting a member into a VO - and the assessment is based on specific trust criteria for that specific purpose, the evaluated trust level results are referred to as the *specific trustworthiness* of that organization.
- ✦ **Trust level assessment:** refers to the examination of the trustworthiness of an organization using certain defined indicators. Many approaches are used to assess different entities' level of trust. As addressed in Chapters 3 and 5, we propose a multi-criteria approach for analyzing the trust in organizations. Based on this approach, rational mechanisms have been developed to assess the level of trust in organizations.
- ✦ **Trust relationship:** a relationship is a state of connectedness between people or organizations, or a state involving mutual dealing between people or parties. Here, trust relationship refers to the state of connectedness between a trustor and a trustee whose intensity is characterized and based on the trust level.
- ✦ **Time:** a trust relationship (and its intensity) between the trustee and trustor is time-bound and may thus differ from day-to-day. In other words, an organization's level of trust is not static and may alter with time, depending on the number of changes to specific aspects used in the assessment. Therefore, the time at which the results will be applied needs to be considered when analyzing trust in VBEs.

1.4 Research motivation and problem area description

In Section 1.2.4 we addressed the need for the establishment and management of trust in VBEs. For example, one key need in relation to trust described in that section is the identification of potential trustworthy VO partners. In this section, we present the main research motivations for the thesis and describe a few exemplary representative problems related to analyzing inter-organizational trust. Three specific example cases are used for this purpose and the focus is on addressing the identification of potential VO partners. The aim of presenting these real examples is to clarify the challenges relating to this problem area and to illustrate the different level of complexities faced by trustors.

The three example scenario cases below address the selection of trustworthy organization(s) for invitation to participate in a VO, and focus on (1) *delivering expensive and delicate products to the market*, (2) *providing support services to street children*, and (3)

building a parliament house. Different sets of requirements, criteria, and so on become of main concern/preference to the trustor, in the process of measuring the trustworthiness of trustee organizations, depending on the “objective” for the assessment/establishment of trust as further described below.

i) Case I: A VO to deliver expensive and delicate products (VO-EDP)

Imagine that a broker has acquired a business opportunity in a market which will address the delivery of expensive and delicate products (e.g. flat screen LCD TVs and laptops) to the market. The delivery needs to meet the large demand of the geographically distributed market - such as the European market or African market - and the organizations involved need to be capable of covering both pre-investment, such as transport means, and insurance during transportation.

With the help of the VBE administrator, the broker then appoints a VO planner. One important task for a VO planner is to select suitable VO partners among the VBE member organizations. A VO planner must select the most trustworthy organizations to be invited into the VO on the basis of the specific objective. Since the main requirement in the case of this VO is that the potential partners are capable of covering the costs of pre-investments and certain potential losses that may occur during the operation phase of the VO, such as some damage to the products, the VO planner may focus primarily on assessing the *economical trustworthiness* of the organizations. Consequently, *capital and financial stability* will be considered as the fundamental aspects (Section 3.3.1) that have to be met by the potential VO partners. The set of exemplary measurable parameters in this case, the values of which must be available from organizations at the VBE, might include *cash capital, physical capital, profits from past VOs* and *operational capital*.

ii) Case II: A VO to provide support for street children (VO-SSC)

In developing countries, the problems relating to street children (children who are homeless and thus live on streets without proper support of food, shelter, clothing, etc.) are serious and ever-more challenging. As an example, therefore, we consider an international organization that wants to configure a VO that will constitute the following two types of partners: (1) Organizations that are capable of providing funding to support the acquisition of resources necessary for the provision of services to street children in certain cities in a country, and (2) Representative organizations in the local cities those are able to deliver the necessary services to the designated children.

In such a network, namely an international organization that assumes the role of the VO planner, the social life of these children is of paramount importance. Therefore, the potential VO partners should also have the same perception and concern for the social values pertaining to this problem. The provision of social support to people should be of particular primary importance in the daily business of the respective organizations, and must be proven by some rational (fact-based) data. This means that *primarily*, the VO planner might assess the *social trustworthiness* of the potential VO partners. Exemplary factors such as community service provision, community standards commitment (e.g. child labor laws) and so on (Section 3.3.1) will be considered for the assessment of organizations' level of trust in this case.

Furthermore, the VO planner prefers the local partners to be capable of using certain internal resources, such as employees, to deliver the required services. Therefore, the number of employees, personnel expertise, number of branches/offices, organizational competencies, and so forth of the local organizations might be the second most important aspect for the VO planner in his evaluation of trustworthiness. As a result of this, the *structural trustworthiness* of potential partners will be also assessed.

Lastly, each organization - and in particular local organizations - should be able to support themselves financially in any activities that are not directly related to the delivery of the service. For example, the costs of visits by employees to the centers where the children are hosted should be covered by the respective organizations. As a consequence, the economical stability of the potential local organizations needs to be taken into account. The VO planner may thus also prefer to assess the *economical trustworthiness* of the local partners.

iii) Case III: A VO to build a parliament house (VO-BPH)

A parliament is a legislature, especially in those countries that have a governmental system based on the Westminster system of government, which is modeled after that of the United Kingdom system. The construction of a parliament house needs to carefully address many aspects such as security, facilities and privacy. The configuration of a VO to build such a house is a challenging task and especially when it comes to the selection of potential trustworthy partners for invitation to join such a VO. The construction of such a VO is not only costly, but also touches the interests of the entire public in the country and demands modern and complex technologies for both ensuring security and providing high quality results.

To be selected to join a VO, the image that the potential partners (usually reputable organizations) portray to the entire public is fundamentally important. Traditionally, the image of an organization is represented by its managerial image, both internally and externally. Consequently, the issues related to the management of organizations, such as experience and stability, as well as past opportunistic behavior, corruption scandals, and so on shall be considered in the evaluation of the *managerial trustworthiness* of potential partners. However, since the privacy and security of the building must be ensured, the technology to be used must be both available and proven within the organizations. Therefore, although experience and the ownership of technology within an organization are not the only factors, they are certainly fundamental ones. In conclusion, the VO planner will *primarily* assess both the *managerial* and the *technological trustworthiness* of the potential partners.

Moreover, inviting an organization with a bad social image - such as that caused by failing to meet certain community standards - into the VO of this particular project may also have negative implications in relation to the future of the entire project. Therefore, organizations' social images are also a fundamental aspect that needs to be assessed when establishing the trustworthiness of the potential partners. Furthermore, the plan for the construction of such houses needs to remain confidential; despite signing the contract, the VO planner may need assurance that confidential material, such as the security mechanisms for the building, will not be disseminated outside VO partners. As a consequence, the availability of, for example personnel experts, competencies, and so on within the organization also becomes important. Hiring temporary employees from other organizations for the purpose of providing the skills needed in the project is quite discouraged. Therefore, the specific trustworthiness of potential organizations will also be assessed in relation to their internal structure. In this case, the VO planner will *secondarily* evaluate both *social* and *structural trustworthiness* of the potential partners. Lastly, the potential partners must be able to invest a priori in the project towards the first payment, which means that they also need to be financially strong and stable, especially in relation to operational capital. Ternary consideration for the VO planners may therefore include the *economical trustworthiness* of potential partners.

Analysis of the complex nature for inter-organizational trust

The trustors as described in the three example cases above (VO-EDP, VO-SSC, and VO-BPH) are concerned about different aspects relating to the evaluation of their potential partners'

trustworthiness for the purpose of inviting them into the respective VOs. Even when the same aspects are considered, the order of importance and preferences usually vary (Table 1.1). This shows that different specific parameters need to be applied for assessing potential VO partners' level of trust, depending on the VO's objectives.

Table 1.1: Summary of trustor organizations' concerns and preferences for trust assessment

	VO-EDP	VO-SSC	VO-BPH
Economical trustworthiness			
Social trustworthiness			
Technological trustworthiness			
Managerial trustworthiness			
Structural trustworthiness			

Primary	Secondary	Ternary	No interest
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The three cases presented above reveal that there are a large number of open issues to be addressed in order to enhance the management of trust among organizations in VBEs. These issues include:

- (a) Differences in concerns/preferences for the aspects that are considered by trustor organizations to assess trust level of trustee organizations.
- (b) Variations of requirements and purposes for the assessment of trust level of organizations, which in turn influences the perceptions of trust of the trustor organizations.
- (c) The identification of diverse trust elements to support any emerging concern/preference of trustor organizations.
- (d) The identification and modeling of inter-relations among factors (trust elements) to support the analysis of inter-organizational trust and to provide reasoning about the results achieved.
- (e) The management of fact-based data for parameters preferred by the trustor organizations and the collection (provision) of those data from organizations involved.
- (f) Mechanisms to dynamically support the rational assessment of trust level of organizations, taking into account the changing parameters.
- (g) The development of services supporting processes related to the management of trust between organizations, such as processes for assessing organizations' level of trust, mechanisms for establishing trust relationships between organizations, etc.
- (h) The provision and presentation of the resulting levels of trust, which must be as understandable as possible to all of stakeholders in the environment, regardless of their expertise on trust and such aspects.

These open issues are among those addressed in this thesis as contributions towards providing the approaches, mechanisms and tools needed to support the management of inter-organizational trust in VBEs. In the following section we present more details regarding the research questions addressed by this thesis. Each of the above listed open issues is addressed by at least one of the open research questions indicated in Section 1.5.

1.5 Research questions, objectives, and scope of the thesis

A number of research questions must be properly addressed to support the realization of rational trust in VBEs. It is clear that trust relationships between organizations play a pre-

conditional role in achieving smooth and successful cooperation in VBEs and collaborations in VOs. The following series of main research questions (MRQ) and their respective sub research questions (SRQ) are addressed in this thesis.

MRQ1: How the diversities in the purposes for which trust among organizations need to be established (from trustor to trustee) as well as trustor's concerns and preferences can be handled?

This first main research question - which covers open issues (a), (b), and (c) mentioned in Section 1.4 - is primarily related to the characterization of inter-organizational trust as applied in VBEs. It is addressed mainly in Chapters 3 and 5. These chapters address different possible perceptions about organizations' trust and their preferences on the set of related trust criteria to be used for assessing organizations level of trust. This main question has the following two sub-questions.

SRQ1.1: Which trust criteria and how many must be applied to measure an organization's level of trust in a VBE?

We present an approach for identifying trust elements in Chapter 3 and also an approach for customizing the mechanisms to assess organizations' level of trust in Chapter 5. These two chapters collectively address the following sub-question:

SRQ1.2: Which values of trust criteria shall be improved by a trustee organization in order to reach higher trustworthiness within a VBE?

In Section 2.4, we present aspects that can be considered while deciding about the required trust related data to support the establishment of trust between organizations. In Section 2.5, we propose systematic steps for establishing sustainable trust relationships among organizations in VBEs. These proposed steps are supported with defined approaches and/or functionalities (addressed in Chapters 3, 5, and 6) for creating trust among involved organizations.

MRQ2: How can the understanding of many elements and concepts related to rational trust within a VBE be supported for its stakeholders?

This second main question, which covers open issues (a), (b), (g) and (h), is primarily focused on modeling inter-organizational trust related elements. It is mainly addressed in Chapter 4 and it has one following sub-question:

SRQ2.1: What models can suitably represent the concepts related to both trust and trust relationships between organizations?

In Chapter 4 we discuss the modeling needs related to trust and we present three kinds of modeling approaches for trust and trust relationship between organizations. In this chapter, we thus address both the main question and its sub-question.

MRQ3: How can formal mechanisms be developed to rationally assess and formally reason about the level of trust in organizations?

The third main research question mainly addresses four open issues, namely as listed earlier in items: (c), (d), (e), (f) and (g) in Section 1.4. Primarily, this question is related to the development of mechanisms for measuring the level of trust in organizations within a VBE. It has the following four sub-questions:

SRQ3.1: Can the level of trust in an organization be rationally measured within a VBE?

SRQ3.2: What is the relation between every measured trust criterion and the level of trust in an organization?

SRQ3.3: How to analyze the inter-relations and influences among different trust criteria?
SRQ3.4: How to develop formal mechanisms for assessing trust level of organizations?

In Chapter 3 we present an approach for analyzing the inter-relations among rational trust elements as well as examining the influence of each factor to the trust level of an organization. To address the influence of a factor to the trust level of an organization, we present an impact analysis approach to analyze the impact of varied values of one factor on the trust level of an organization. Further, to address the inter-relations and influences among rational trust elements and in particular the measurable criteria, we present the causal analysis approach, applied for analyzing the causal influences among different trust factors. The results of causal analysis are then formulated into mathematical equations. Later on, in Chapter 5 we introduce formal mechanisms for assessing trust level of organizations, applying the mathematical equations derived from the analysis of causal influences among trust criteria. Therefore, in Chapters 3 and 5 we address this main question and its four sub-questions.

MRQ4: How can the establishment of inter-organizational trust relationships in VBEs be facilitated?

This fourth main research question covers open issues (a), (b), (d), (e), (f), (g), and (h) and is primarily related to the development of trust management support system. In Section 2.5 we present fundamental steps that can be followed to assure the establishment of sustainable trust relationships between organizations. In relation to those proposed steps, in Section 2.5 we thus address the following first two sub-questions.

SRQ4.1: How to convince involved organizations about trustworthiness of others?
SRQ4.2: How to sustain inter-organizational trust relationships in VBEs?

Furthermore, in Chapter 6 we present the Trust Management (TrustMan) system, which provides services that can be invoked with other remote systems and as well web-based functionalities that are accessed by human users through the web. The services are designed to support trustors to properly analyze trust of trustees in order to make informed decision while establishing trust relationships. In Chapter 6, we thus address this main question, as well as its sub-question that follow.

SRQ4.3: How can the trust management system facilitate establishment of trust relationships through both periodical and occasional measurements of organizations' rational trust level?

The main contributions this thesis makes are thus achieved by answering the above series of research questions. *The approach designed for identifying trust elements for organizations* (Chapter 3), *the developed mathematical (conceptual) models applied to formulate mechanisms for assessing level of trust* (Chapter 5), and *the designed/developed trust management system* (Chapter 6), however constitute the main contributions of this thesis. These contributions are further complemented by fundamental aspects of our research, namely comparisons with existing work and the characterization of aspects of inter-organizational trust (Chapter 2), and modeling identified trust elements (Chapter 4). Therefore, through the integration of these contributions we have achieved the following two main research objectives:

Achieved Research Objective 1 (RO1):

To properly support the management of trust aspects in VBE, providing generic and comprehensive “concepts, approaches, mechanisms and models” needed for supporting:

- Common understanding of the aspects relating to rational trust,
- Assessment of organizations’ level of trust,
- Creation of inter-organizational trust,
- Establishment of trust relationships between organizations”.

Achieved Research Objective 2 (RO2):

Providing a validated prototype implementation for a trust management system in VBEs in order to assist organizations in achieving various trust-related objectives.

In Chapter 7 we analyze how the research carried out in this thesis has achieved these two objectives. The scope of the research addressed in this thesis is at the level of organizations, and primarily applied to the VBE environment. Furthermore, rational trust among organizations is the focus of this thesis. However, when needed, also the subjective trust and inter-personal trust are briefly addressed, to enhance the presentation of the focused topics.

1.6 Research methodology

The methodology applied in our research is classified into four phases that are shown in Figure 1.3. Each phase produces results that are used as input concepts in the subsequent phases. Describing and defining these phases supports the understanding of their inter-relations.

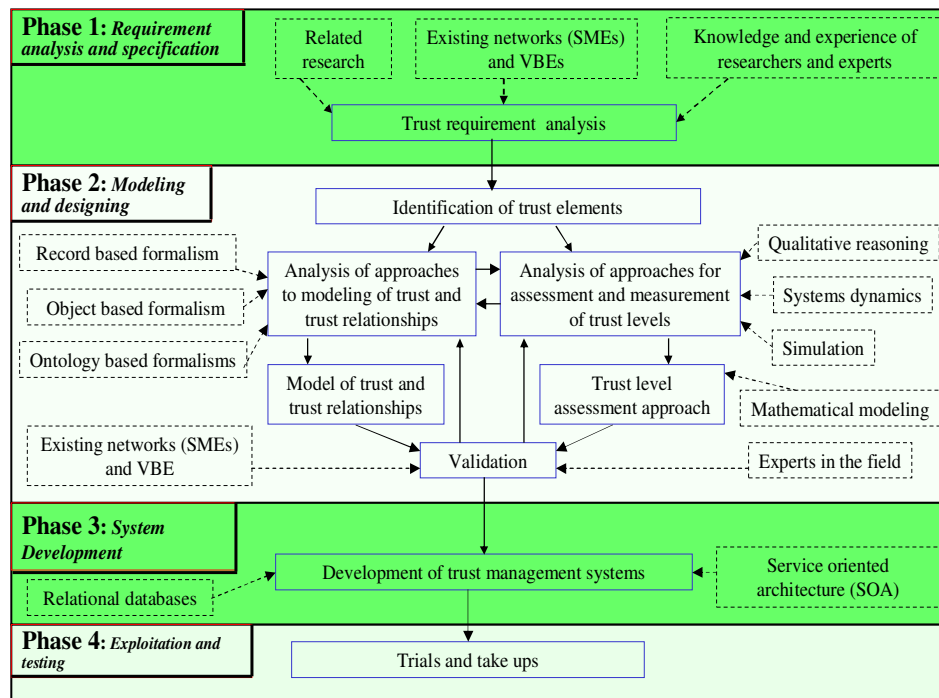


Figure 1.3: The detailed methodology that was followed during our research period. The Solid-line boxes represent tasks that were performed in our research and whose output contributed to the results that are reported in this thesis. Dash-line boxes represent concepts, theories, knowledge of experts, or research results that were considered as potential input materials to our research.

Phase 1: included an analysis and specification of the requirements for the management of trust between organizations in a VBE.

Phase 2: focused on analyzing and defining approaches for modeling trust and trust relationships. It also focused on analyzing and defining approaches for assessing organizations' level of trust. These two analyses addressed requirements related to managing inter-organizational trust, as identified in phase 1.

Phase 3: addressed the development of a trust management system. The development of this system applied the requirements specified in phase 1 and the trust models and mechanisms for trust level assessment that were designed in phase 2.

Phase 4: addressed the testing phase of the developed approaches and the systems in the real environments, such as to support VBEs with managing trust between their member organizations. This phase also considered the potential future areas and domains for exploiting the results of this research.

1.7 The ECOLEAD project and related scientific publications

The work presented in this thesis was carried out partially within the ECOLEAD project. The research on inter-organizational trust was one of the many fundamental topics addressed by this project. In this section we provide a short overview of the research achievements related to the fundamental topics addressed in the project.

1.7.1 The ECOLEAD project

Reinforcing the effectiveness of collaborative networks and creating the necessary conditions for making them an endogenous reality in the worlds of business and industry - mostly based on SMEs - is a key factor for the globalization of an economy. Collaborative networks provide a basis for competitiveness, world-excellence, and agility in turbulent market conditions. They can support SMEs in the identification and exploitation of new business potential, boost innovation, and increase an SME's capabilities. The networking of SMEs with large-scale enterprises also contributes to the success of larger companies in the global market. This was the key motivation for the ECOLEAD project.

ECOLEAD stands for European Collaborative networked Organizations LEADErship initiative. This project aimed at creating the necessary strong foundations and mechanisms for establishing advanced collaborative and network-based industries. The fundamental assumption in the project was that a substantial impact in materializing networked collaborative business ecosystems requires a comprehensive holistic approach. Assuming that given the complexity of the area and multiple inter-dependencies among involved business entities, social actors, and technologic approaches, substantial breakthroughs cannot be achieved with incremental innovation from isolated areas. As such, ECOLEAD addressed three most fundamental and inter-related areas of focus – its vertical pillars - that are the basis for dynamic and sustainable networked organizations, including: (1) *Virtual Organization Breeding Environments*, (2) *Dynamic Virtual Organizations Management*, and (3) *Professional Virtual Communities*.

The work presented in this thesis was mostly achieved in ECOLEAD project, and specifically in relation to the *Virtual Organizations Breeding Environments*. The ECOLEAD project proposed a holistic approach, reinforced and sustained on two horizontal layers: (1) *Theoretical foundation for collaborative networks*, and (2) *Horizontal ICT infrastructure*.

These two layers are “horizontal” in the sense that they support and affect the three areas of focus as vertical pillars. The theoretical foundation provides the basis for technology-independent understanding of the area and its phenomena. Furthermore, the existence of an invisible, horizontal ICT infrastructure is a pre-condition for the establishment of truly dynamic collaborative networks. The conceptual, methodological and prototypical results of ECOLEAD significantly impact the industrial competitiveness and societal mechanisms by providing means to effectively exploit opportunities deriving from the deployment of VOs, and by designing and enabling new professional work paradigms capable of enacting knowledge-based societies. Figure 1.4 shows the logo of ECOLEAD indicating the inter-relations among its five areas of focus.

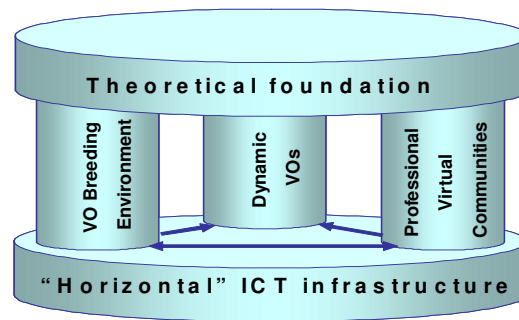


Figure 1.4 : ECOLEAD logo showing main areas of focus

This figure shows the five main focus areas of the ECOLEAD project. This research falls within one of sub-areas, namely the VO breeding environment.

We briefly addressed the notion of the VBE (VO breeding environments) in Section 1.2. Below we briefly address these five main areas of focus of the ECOLEAD project.

a) *Virtual organizations Breeding Environments and their management*

This area of focus addresses support for establishment and management of VBEs, by performing comprehensive requirement analysis, and provision of methodologies, concepts, mechanisms and functionalities to support administration of VBEs. This is achieved through developing adequate VBE organization models, establishing operating principles, and providing ICT facilitating tools. Therefore, the area of focus mainly addresses the following three categories of challenges:

- i) *The characterization and typology of VBE environments*: This topic addresses the characterization of a VBE’s constituting elements, actors, and features; as well as defining a VBE’s working and sharing principles. It also focuses on the definition and modeling of organizations’ competencies, expertise, skills, and so on, and the development of methods to gather and organize such related information. Furthermore, this topic addresses the establishment of a common ontology in a VBE that supports the harmonization of a conceptual understanding between VBE actors. Finally, it addresses the identification of a

common value system and the development of mechanisms to guide the creation of inter-organizational trust in a VBE.

- ii) *The development of a VBE management system*: this topic addresses the specification, design and implementation of functionalities and services that are necessary to support the management of the VBEs. As further addressed in Chapter 6, a number of fundamental functionalities (subsystems) which constitute the VBE managements system were specified and developed. These functionalities mainly support the management of VBE structure and membership, organizations' competency aspects, inter-organizational trust, management of VBE's bag of assets, and decision support systems and so on.
- iii) *Support for the creation of VOs within VBE environments*: this topic addresses how to find and characterize VO related opportunities in the market and society, and mechanisms for VO planning, intelligent matchmaking and launching. It also addresses the provision of a negotiation support framework that helps potential VO partners to smoothly reach consensus/agreement on discussions concerning the respective VO. Provision of services to support all steps and activities necessary to create and launch a VO are also further addressed in Chapter 6.

b) *Dynamic VOs and their management*

This area of focus addresses the methodologies, models, services and management tools that are needed to support the initiation, operation and dissolution of virtual organizations. A holistic approach to dynamic VO management is achieved in the ECOLEAD project and with the integration of concepts from other areas of focus.

The main challenges for VO managements are influenced by the following two aspects: the temporary nature of dynamic VOs and the distribution of processes in independent organizations that have to collaborate to achieve common goals, while their own interests are also being met. As illustrated in the ECOLEAD project, an effective VO that achieves its goals throughout its life cycle can seldom be configured without the need for a preparatory environment – a VBE. The most challenging aspects of managing dynamic VOs to be identified by ECOLEAD included:

- i) The basis for VO management models, which was addressed through an investigation of the distributed business process modeling, decision-making methods, VO management support tools and VO categorization. The basic framework for dynamic VO management was achieved.
- ii) A VO Performance Measurement system constituting a methodology supported by a software tool was achieved. This system takes into account multi-objective and VO-specific multi-perspective approaches. It also addresses the distributed business processes, pro-active management, analysis methods and decision support. The performance of organizations are measured during the operation phase of a VO and transferred to a VBE as inheritance during the VO dissolution phase.
- iii) The governing principles of VO dissolution and inheritance management were also addressed to support the transition from operation phase to the dissolution phase. This also supports the transfer of inheritance from a VO to a VBE, which include dissolution management, joint knowledge management and the ownership, collection and management of outputs and results created by the VO concerned (IP ownership, liabilities and enforcement mechanisms).

c) Professional virtual communities

This area of focus addresses the methodologies, mechanisms, and approaches needed to jointly establish a robust framework for the deployment of Professional Virtual Communities (PVCs). It also addresses laying the foundation for new methodological and technological frontiers that provide collaborative approaches and knowledge sharing within the different scenarios of Virtual Communities.

In the ECOLEAD project, the PVC was defined as: *an association of individuals that are explicitly pursuing an economic objective identified by a specific knowledge scope, with the aim of generating value through members' interaction, sharing and collaboration, which is optimized by the synergic use of ICT mediation* [Crave, et al., 2006]. ECOLEAD dealt with the fundamental challenges in the establishment of PVCs by addressing the following aspects.

- i) The identification and specification of the base requirements, and their related social or legal implications.
- ii) The development of models that represent and support the understanding and deployment of the requirements for establishing and managing PVCs.
- iii) The designing and implementation of ICT support facilities, and operating principles to help individuals join and remain part of PVC.
- iv) The development of supporting tools required for proper functioning of communities and related supporting entities.

PVCs are analogous of VBEs, their main differences being their constituent members. While in VBEs the smallest entities considered to be member are the organizations, in PVCs individuals constitute the members. PVCs are communities in which virtual and remote coordination is the rule and geographical regrouping is practiced. Typically, such communities are established with certain business objectives in mind and for this reason PVCs are still believed to emerge in future business scenarios [Crave, et al., 2006]. However, various types of communities, such as practice communities and epistemic communities, demonstrate certain similar characteristics that may be considered in PVCs

PVCs are therefore long-term strategic alliances involving individual professionals who join their initiatives for the purpose of enhancing their preparedness for involvement in emerging and acquired business opportunities. Once a business opportunity is brokered, potential individuals are selected and invited to form a consortium. This form of short-term consortium involving individuals and configured for the purpose of addressing a specific business opportunity is called a *Virtual Team (VT)*.

d) Horizontal ICT infrastructure

This area of focus addresses the establishment of a strong foundation for an ICT-independent infrastructure that supports the operation and interoperability of various tools and systems within the CNO environments. ICT infrastructure also provides functional, organizational and technical services that fundamentally impact each enterprise, global consistency, and interoperability. Owing to the heterogeneity of the Enterprise Applications and the dynamics of the business relations, the Enterprise Applications Integration in the form of the "federated model" has been the most suitable for traditional collaborations. However, CNOs need to study and incorporate more efficient approaches that address short time impacts and new technological standards. Furthermore, the following series of questions are usually raised when establishing a business model:

- ✦ Who is the provider of services?
- ✦ What are the technical and commercial requirements?

- ✦ What is the product?
- ✦ What are the benefits for respective stakeholders of this product? and;
- ✦ What is the market and what is the marketing plan?

Business models need to be addressed in order to identify the essential requirements for the approach - namely the essential modality of doing business and the essential cost/benefit plan - so that it may be accepted and that stakeholders are willing to pay for these services. The following aspects with respect to ICT-infrastructure were considered in order to address the technical and business model requirements:

i) The development of a reference architecture that covers different forms of collaboration (ad-hoc, mediated, pre-planned, etc.), the different stages of the collaboration life cycle (initiation, planning, operations, dissolution, etc.), and in order to be independent from the sector (industry, government, etc.), the application (supply chain, e-learning, etc.), the number of the organizations involved and the typology of the network (chain, ecosystem, etc.). In order to develop a comprehensive architecture in particular the following aspects were considered:

1. A framework for ICT technology-independent reference architecture for collaborative networks.
2. The foundation of interoperability principles derived from past R&D on VO.
3. Approaches for enterprise applications, integration and interoperability.
4. Semantic mediation over formats, protocols and models through multi-language differentiation mediation.
5. A base prototype infrastructure mapping the reference architecture to current / emerging technologies.

ii) The defining and devisal of business models for the developed ICT infrastructure. The deployment and maintenance of ICT infrastructures require different approaches than the traditional ones and must consider the emerging business characteristics and nature of CNOs. It addresses:

1. The elaboration of suitable business models and characterization of stakeholders in the “CNO infrastructure” business.
2. Cost-efficient deployment methods for business models.
3. Assessment models and methods for business achievements of the ICT infrastructure.

iii) A security framework based on an independent ICT infrastructure. Two aspects were addressed, which together contribute to the security framework:

1. Security by establishing trust between several partners that aim to collaborate in a certain business opportunity. What are the key criteria for assessing not only individual trust in a digital or virtual market, but also organizational trust? This aspect is addressed in this research as a technological aspect of trust.
2. Security by developing tools, technologies, digital signature, data encryption and private networks that can protect knowledge, intellectual property or the competitiveness of the VO, the PVC and each contributor.

e) Theoretical foundation for CNOs

This area of focus addresses the establishment of a sound theoretical foundation for collaborative networked organizations through the promotion and assessment of the adoption of formal and semi-formal modeling methods and tools, as a means to consolidate the

fragmented existing and emerging knowledge in this area. The establishment of a theoretical foundation follows a similar approach to that of the *establishment of a new scientific discipline*. One of the first steps in this concept is to address the assessment and adoption of promising theories and formal modeling methods that have been developed in other disciplines. The following aspects were addressed to build a comprehensive theoretical foundation for CNOs:

- i) The collection and assessment of contributions from other disciplines that can provide a starting basis for a rigorous theoretical foundation and formal modeling approaches for collaborative networks. The main modeling facets or purposes (e.g. structure, roles, behavior, processes) were identified and a set of modeling tools and base theories were proposed for each one.
- ii) The elaboration and formulation of a reference model for collaborative networked organizations. The concept of “reference model” itself in relation to CNOs was well-established and the main business entities (breeding environment, virtual organization, and professional virtual community) were covered. This included:
 1. The consolidation of CNO concepts and their abstraction in terms of a general reference model (semi-formal and easily understandable by humans)
 2. The development of an engineering methodology for the purpose of applying the reference model
- iii) The establishment of a reference framework for CNOs was another important task in this area of focus. A comprehensive reference framework is proposed that covers the concepts involved in all forms of CNOs [Camarinha-Matos & Afsarmanesh, 2006].

1.7.2 Scientific publications related to the dissertation

The bulk of the content of this thesis has already been published in different forms, including book chapters, journal articles, international conference papers (peer reviewed) and technical reports, e.g. ECOLEAD project deliverables. The table below is a summary of the author’s publications, according to the different subjects addressed in the thesis. The numbers in the table above include both those papers that are published and those accepted for publications. A detailed description of author’s publications is provided in Annex A.

Table 1.2: Summary of author’s publications

Subject covered	Journals	Book chapters	Conferences	Technical reports	Total
Requirement analysis and specification on trust	1	1	2	2	6
Modeling and designing mechanisms and systems for trust level assessment	2	1	2	5	10
Developing and testing the trust management system	4	1	3	4	12
Total	7	3	7	11	28

Table 1.2, which will also be partially indicated later in every chapter, shows how aspects of this thesis (namely trust modeling, assessments, and management) have already appeared in a relatively large number of publications read by organizations that are involved in cooperation / collaboration.

1.8 Thesis structure

This thesis addresses the approaches, mechanisms and tools that are used to support the management of inter-organizational trust within VBEs. Its structure conforms to the inter-connections between the subsequent presented results. The results are inter-related in the sense that the concepts presented in each preceding chapter constitute a fundamental contribution to the understanding of successive chapters. The following structure has been adopted to facilitate the readability and understandability of the thesis.

✦ ***The results on requirement analysis and specification of trust are addressed in:***

Chapter 1: This chapter has introduced the problem area addressed in this thesis and has presented the domain in which the produced research results are applied. First, it has presented at high-level the research challenges addressed in the thesis and then briefly introduced the proposed solution for each challenge. Second, it has addressed the discipline of collaborative networks which is the domain in which our research results are applied. Third, the chapter has analyzed various background definitions of trust and presented the base concepts of trust. Fourth, it has presented three examples of cases of application in order to describe the research motivation and problem area addressed in this thesis. Fifth, it has presented the objectives, the motivating research questions, the scope and the applied methodology to this research. Finally, the chapter has introduced the project – ECOLEAD – in which this research was conducted.

Chapter 2: This chapter presents the general concept of trust and introduces the characterization of inter-organizational trustworthiness. Firstly, it surveys existing work on inter-personal trust and then compares this with inter-organizational trust. Secondly, it surveys related work on trust as addressed across different disciplines, such as sociology, psychology, computer science, and so forth. Finally, it introduces the characterization of inter-organizational trust in VBEs. This chapter presents also fundamental steps to guide the establishment of inter-organizational trust relationships in VBEs. The proposed steps consider the fundamental contributions of this thesis, namely the classification and characterization of trust elements as presented in Chapter 3, the assessment of organizations' level of trust, as presented in Chapter 5, and the services for supporting the management of inter-organizational trust, as presented in Chapter 6.

✦ ***The results on modeling and designing mechanisms and systems for the assessment of trust level are addressed in:***

Chapter 3: This chapter addresses the identification, analysis and characterization of trust elements for organizations. Firstly, it presents the proposed HICI approach and its three main concepts, which also constitute its three stages, namely hierarchical analysis (first stage), impact analysis (second stage), and causal influence analysis (third stage). Lastly, the chapter presents the trust elements that have been identified by applying the HICI approach and which empirically validated by industrial VBE networks.

Chapter 4: This chapter presents the conceptual modeling of trust elements for organizations. Firstly, it presents the related work on trust models that have been developed for different applications, for example e-commerce, inter-organizational network effectiveness, multi-agent systems, and so on. Secondly, it introduces trust parameters and trust elements that are used for modeling inter-organizational trust. Lastly, it addresses three conceptual modeling formalisms applied in this thesis, namely object-based, record-based and ontology-based formalisms.

Chapter 5: This chapter addresses the formulation of mechanisms for assessing organizations' level of trust. These mechanisms are formulated using mathematical equations

that are derived from the results of an analysis of causal influences between different measurable trust parameters. The chapter presents a conceptual model that is used to formulate the formal mechanisms for assessing organizations' level of trust. Firstly, it surveys existing work on the assessments of actors' level of trust in specific environments, such as online communities, social networks, and so on. Secondly, it addresses the concepts relating to organizations' comparative levels of trust and in particular the presentation and interpretation of these levels of trust. Lastly - and with the aid of an example - the chapter presents the approach used to formulate mechanisms for assessing organizations' level of trust.

✦ ***The results on developing and testing systems are addressed in:***

Chapter 6: This chapter presents a Trust Management (TrustMan) system which has been designed and developed to provide services for the management of inter-organizational trust in VBEs. First, the chapter presents a VBE management system (VMS) and its related subsystems (the TrustMan system is one of the many subsystems of VMS); second the chapter addresses concepts applied to implement mechanisms for assessing organizations' level of trust; third, it presents specification of the TrustMan system; and fourthly, it addresses the architectural design of the TrustMan system. Lastly, the chapter presents the implementation of the TrustMan system and its adaptation by industrial VBEs networks.

✦ ***A summary of the results is addressed in:***

Chapter 7 This chapter summarizes the subsequent results of our research and in particular the innovative contributions. It discusses how the results have been accepted in both research and business communities and presents proposed future work in this area of research. Finally, it concludes the thesis.

1.9 Chapter discussion and conclusion

This chapter has introduced the research problems addressed in this thesis. In order to enhance the presentation of these research problems, the descriptions of the base trust concepts have been given. The concepts related to the application domain for this thesis – the VBE – are also addressed. Based on the research problems, a number of research questions are stated, which in turn guide the formulation of the research objectives. Lastly, the structure of this thesis is also presented in this chapter, which details the inter-relations and flow of concepts presented in this thesis.

The emergence of collaborative networks as a scientific discipline marks another step in scientific and engineering developments. This thesis addresses a fundamental topic in this discipline by introducing a new approach that can be used to analyze “inter-organizational trust”. The research challenges introduced in this chapter are systematically addressed in this thesis (as described in Section 1.8) in order to give a clear presentation of the innovative contributions that support this research.

Therefore, this chapter has presented the base concepts of inter-organizational trust that are necessary for further understanding of the research results presented in the remaining parts of the thesis. It has also presented the main research challenges and research questions that one by one are addressed in the next chapters.

