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

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# Chapter 4

## Conceptual modeling of trust elements

*The perceptions, preferences and interpretations of trust differ among the organizations, as addressed before, depending on their purposes for establishing trust relationships with others. As a result, different organizations consider different aspects when analyzing trust in other organizations. Thus a large number of aspects must be properly specified and modeled to comprehensively cover the trust objectives of organizations. In addition to a survey of existing work related to modeling trust, this chapter analyzes and proposes three specific modeling formalisms (namely, record-based, object-based, and ontology-based formalisms) that best represent trust relationships among organizations and presents some examples.*

*This chapter has been partially published in the International Journal of Technology Transfer and Commercialization [Msanjila & Afsarmanesh, 2007b].*

### 4.1 Introduction

Considering the key role that trust plays in facilitating collaboration within VBEs, understanding the base concepts relating to inter-organizational trust is necessary for creating successful collaborative networks of organizations. This chapter examines conceptual modeling of trust relationships between organizations, which fundamentally contribute to creating a common understanding of inter-organizational trust among its different actors. In Section 4.2 we first present a survey of related research on trust models and subsequently, in Section 4.3, we address the conceptual modeling of trust relationships between organizations that assist us with characterizing inter-organizational trust. In Section 4.3.1 we present the main trust parameters applied in developing models of inter-organizational trust relationships. In Sections 4.3.2, 4.3.3, and 4.3.4 we present three modeling formalisms that are applied in this thesis to model different aspects of trust, namely: *object-based conceptual formalism, record-based conceptual formalism and ontology-based conceptual formalism*, respectively.

### 4.2 Related trust models in research and development

Research on trust is characterized by a substantial diversity in disciplinary background, methodologies, models, and definitions. These differences result mainly from different actors' perceptions of what it means to trust. By the same token as the differences in interpretation of trust, diversity also exists among the current trust models developed by these same researchers. Several examples of trust models are discussed below, and although they are originated and applied in environments different from VBEs, each one presents some aspects that are related to the VBEs:

***i) An integrated model of trust in e-commerce***

Electronic commerce, commonly known as ***e-commerce***, refers to buying and selling of products or services over electronic systems such as the Internet and other computer networks. A wide variety of commerce is conducted in this way, spurring and drawing on innovations in a number of business aspects including: electronic money transfer, supply chain management, internet marketing, online transaction processing, electronic data interchange, inventory management systems, automated data collection systems, etc. Modern e-commerce typically uses the World Wide Web, at least at some point in the transaction's lifecycle, although it can encompass a wider range of technologies, such as e-mail as well. A large percentage of e-commerce is conducted entirely electronically for virtual (non-physical) items, such as access to premium content on a website, issuing electronic tickets for flights, etc. However, other e-commerce transactions may also involve the transportation of physical items to buyer in some way once the ordering and payment are accomplished electronically.

Past research has pointed out a number of challenges that need to be addressed in order to facilitate the full realization of e-commerce. Some few challenges to exemplify here are: authentication of users with their specific and unique identification and role, assurance of the privacy of involved actors, support for online negotiation, management of online payments, personalization of e-commerce services, establishment of suitable infrastructures, creation of support software, etc. [Keen, 1999]. In addition to these challenges, one more key challenge, related to research addressed in this thesis, is the establishment of trust among actors involved in the e-commerce transactions. In fact transactions taking place in e-commerce are similar to the business processes conducted and/or supported in VBEs, in the sense that they are both handled virtually and in distributed environments. Thus the concepts of trust among actors involved in e-commerce transaction and in particular, the e-commerce related trust models can be fundamental input to understanding and modeling inter-organizational trust.

To support the understanding of trust among actors in e-commerce and its related transactions, Kini and Choobineh [1998] have developed a theory that provides a strong theoretical foundation for a set of evaluating factors influencing trust related behaviour. This model is based on the fundamental assumption that trust in an online system is a function of the following four dimensions (as also shown in Figure 4.1): (1) characteristics of the person making the e-commerce transaction, (2) the online system itself that supports the required transactions, (3) the task for which the system is being used, and (4) trust related information and its source environment.

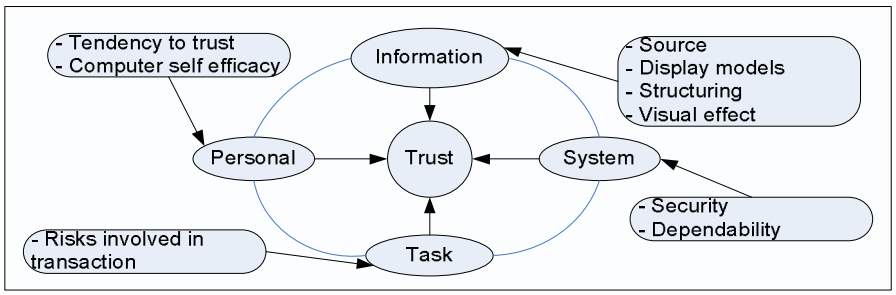


Figure 4.1: An integrated model of trust for E-commerce application

*Based on concepts as presented by Kini and Choobineh [Kini & Choobineh, 1998] this figure shows the influence of four e-commerce related factors and their related aspects on the process of creating trust among actors, as discussed in the following paragraphs.*

As shown in Figure 4.1, all four of these dimensions influence the creation of trust between the partners involved in the e-commerce transactions. In their study, Kini and Choobineh [1998] proposed that it is the ***personal*** characteristics of an individual which determine his/her readiness to trust. Other researchers who have studied individuals' trusting behavior also contend that the readiness to trust is shaped by specific developmental and social-contextual factors [Lee & Turban, 2001]. In this model, this readiness characteristic is called *Tendency To Trust* (TTT). This research demonstrated that people with a high TTT are more willing to trust others when confronted with new situations.

To further understand the TTT in relation to specific transactions, it is important to study the kinds of ***task*** that necessitate trust, and to focus on means of fostering and developing trust in these tasks in order to ensure that *e- commerce systems* can be developed for a wide range of applications.

The sensitivity of a ***task*** being executed using the e-commerce technology might make the creation of trust among e-commerce actors difficult. For example, whether the task needs to be accomplished completely online or some physical processes are needed. Also, the gains expected by actors and the risks that can emerge by handling the task using e-commerce technologies, as compared to other approaches such as physical transactions, might influence the decision of an e-commerce actor to trust others.

The characteristics of the ***system*** with which the user interacts play a critical role in the development and preservation of trust between participating partners in e-commerce-based transactions. Several studies have shown that security is a main factor in the success or failure of online businesses [Msanjila & Afsarmanesh, 2007c]. Other important factors that influence the creation of users' trust in the online system are their perceptions of the dependability and reliability of the system itself.

The ***information*** which needs to be exchanged to support e-commerce transactions has an important role in realizing the required trust among e-commerce actors. The content of information which needs to be exchanged among e-commerce actors must be as accurate, valid, up-to-date and complete as possible. Furthermore, the reputation of the environment where the information is collected *(source's environment)* and usability of environment where the e-commerce actors access the information *(online system interfaces)* might influence the decision of actors to trust others. For example, the usability of the system influences the willingness of customers to in detail read the online advertisements of products and services and thus decide on which provider to trust. The environment presented by the system – user interfaces - should be correctly perceived and understood by users in relation to the presentation and structuring of the information. Therefore, visualization and display models are critical issues that must be taken into account in order for the information to be successfully exchanged among e-commerce actors. The effects of system's user interfaces should be studied in order to guide the design and implementation of suitable interfaces. In particular, it is important to identify whether different presentation modes, such as websites based on frames, multimedia, dynamic/static website, and so on, affect the creation of trust among e-commerce actors using online systems.

The external environments –surrounding environments such as the competitor markets – might also influence the creation of trust between actors by providing them with complementing or contrasting information. It also contributes to the overall perception of the reliability, security, privacy, dependability, etc. of a system supporting the e-commerce transactions. It is important also to understand whether trust in a system can be manipulated by providing information on possible external impacts relating to relevant aspects of the system.

**Relevance to our research:** As described earlier in this section, the virtual and distributed nature of e-commerce transactions is similar in the way business processes are handled and supported in VBEs. In relation to the work addressed in this thesis, the approach for characterization of elements that are included in the e-commerce trust model, as exemplified here, is relevant and complementary. Specifically, concepts presented in this model are applied in our model to analyze a number of trust related aspects among organizations in VBEs, as addressed below:

- *Trust related information to be exchanged among organizations*: We have applied the concepts presented by this model to analyze the content of information that is needed to be provided to a trustor organization in order to trust a trustee organization. Applying the knowledge gained through learning this model we have characterized the content of organizational data related to trust on the basis of five aspects, namely: "*why", "what", "when", "how" and "who"* as further addressed in Section 2.4. We have also applied the concepts presented by this model to analyze the need for information to be accurate, valid, up-to-date and complete for the purpose of enhancing the effectiveness of the process for creating inter-organizational trust.
- *Technological aspects supporting organizational collaboration*: We have considered the concepts presented by this model to analyze the influence of technology (related to technological perspective – see sections 2.3.6, 3.3.1 and 5.5) such as information systems, on the process of creating trust among organizations. The success of creation of trust between collaborating organizations is influenced by a number of various aspects related to the technological perspective. Information and communication systems that are applied by an organization or by the VBE to facilitate the collaboration among organizations can influence the decisions made by those partners about trusting each other. System related aspects, such as security, privacy, reliability, etc., unless handled properly by the VBE and by organizations can negatively influence decisions made by organizations to provide their trust related data to the VBE administrator or the trustor organization. So, there will be a lack of trust related data and as a result organizations will face difficulty in trusting each other.

***ii) A trust model for inter-organizational network effectiveness***

This trust model has been proposed as a means to support and provide guidelines, and act as a driver, to organizations that are participating in cooperation/collaboration networks [Ahuja, 2000]. The aim of this model is to increase the chance of an organization for achieving their common or compatible goals, and thus improving the effectiveness of their collaborative network. The focus of this model is on how inter-organizational networks can benefit from and influence strategic resource acquisition (Figure 4.2). This proposed model addresses factors relating to the structural and relational dimensions of social capital built between organizations in a collaborative network. On the basis of this model, organizations can analyze the effectiveness of their network in relation to the following:

- *How collaboration among organizations influences the potential for achieving common goals.*
- *How achievements of common goals improve the network's effectiveness.*
- *How trust affects organizations' collaboration especially in relation to sharing and exchanging information, resources, etc.*
- *What are the relations between network performance and individual organization's performance?*

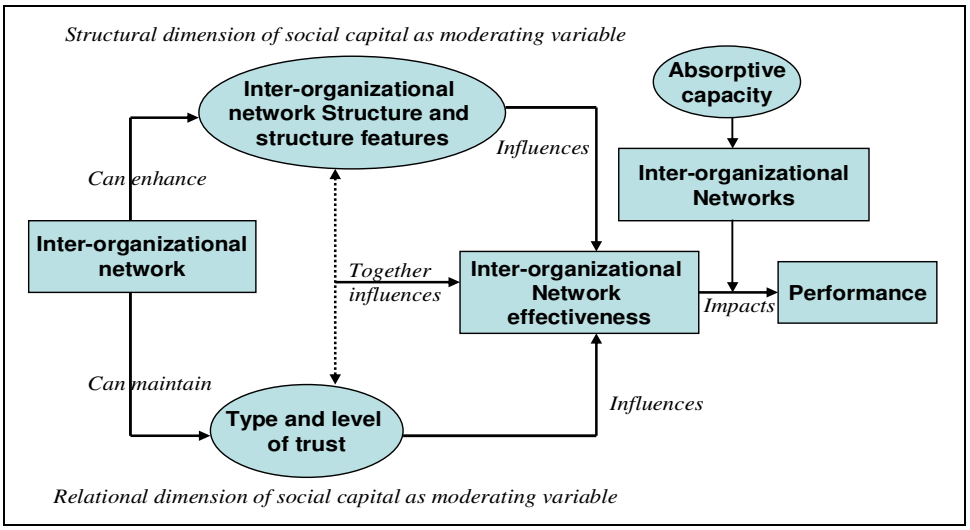


Figure 4.2: Conceptual model for trust and network effectiveness

*Based on the concepts presented by Ahuja [Ahuja, 2000], this figure shows the inter-relations between trust and organizations' performance and other related aspects.*

A collaborative network can ultimately enhance the performance of its individual organizations by supporting different forms of collaboration which best fit the needed response to acquired opportunities. For example, an organization's innovative capabilities are positively impacted by both direct and indirect forms of well-established communication with other organizations. This communication enables knowledge sharing between the cooperating or collaborating organizations and the opportunity for them to provide each other with complementary skills [Msanjila & Afsarmanesh, 2007a]. These different forms of collaboration and their specific transactions reflect different organization configurations in collaborative networks [Ahuja, 2000].

Researchers have explored the impact of collaborative network configurations, focusing on the number of involved organizations and the hierarchies in making decisions, on outcomes and effectiveness of their collaborations [Human & Provan 1997; Gloor, et al., 2008]. The results indicated that the level and range of performances achieved by organizations in networks might be influenced by the number of involved organizations and the manner of their involvement. For example, a network with large number of member organizations has high chance of internally constituting a large set of competencies and thus is able to quickly and efficiently respond to emerging business opportunities. The results also indicated that in a flat network in which decisions are collaboratively made (decentralized network) there is high chance of making acceptable and effective decisions by all involved organizations.

Although communication between organizations alone can represent a significant level of sharing and exchanging resources, this does not guarantee the actual transfer or exchange of strategic resources in the network. There are three fundamental barriers that encumber the transfer of strategic resources among organizations in the network [Szulanski, 1995; Hurmelinna-Laukkanen & Blomqvist, 2007]:

- the receiver's lack of absorptive capacity;

- causal ambiguity within the interactions;
- a weak relationship between the source and the receiver.

It was observed that trust helps to overcome all three of these barriers and that it also encourages an important condition for the exchange of resources to occur, namely the *motivation* [Ahuja, 2000]. Without trust, organizations will be reluctant to share resources due to the fear of possible risks that might arise, such as the opportunism from other collaborating organizations. This model implies that the level of trust affects the number and level of resources that can be exchanged. It also implies that the level of trust is related to the difference between the number of resources that organizations are willing to transfer and the amount that they are actually able to transfer. Consequently, the effectiveness of the collaborative network is dependent on the level of trust from its member organizations. This indicates that the amount of resources acquired through inter-organizational networking is related to the balance of trust levels between organizations.

**Relevance to our research:** As proposed earlier in this thesis (Section 3.2.2), the main input data to the assessment of the trust level of an organization is its performance data. The performance of the VBE as a whole and its configured VOs, represent the collective performance of all VBE involved organizations. Different aspects presented in this model which influences the performance of both – the network and the member organizations – such as the absorptive capacity of organizations, causal ambiguities within the interactions, the willingness to exchange and share resources, etc. - are of particular importance for our model of trust.

We have considered the concepts presented by this model to better understand how VOs need to be configured, and especially related to constituent partners that are selected from the VBE, to enhance the chance of optimizing the performance of both individual organizations as well as the VO itself, which in turn will enhance their trust level. As such, a VO should be configured constituting the set of most trustworthy partners in the VBE for each specific trust objective, as described in Section 6.4.2 (see Service 2) and Section 6.6.1 (see Module 6). As presented by this model, strong trust among organizations has positive impact on the effectiveness of their collaboration and their individual organization's performances, which in turn shows that there is a causal feedback between trust in an organization and its performance in collaborative activities (as described in Section 3.2.2).

***iii) FIRE: Trust model for open communities***

An open community is a group of people that primarily interact via communication media, such as letters, telephone, email or Internet rather than face to face; for social, professional, educational or other purposes. If the mechanism applied to support the interactions among actors is a computer network, such as the Internet, then the community is called *an online community*. The ability to interact with like-minded individuals instantaneously from anywhere on the globe has considerable benefits, such as possibility to acquire knowledge from any place in the world. But these open communities have bred some fear and criticism mostly due to their virtual nature. It has been stated that these communities can serve as dangerous networking or hunting grounds for online criminals, such as identity thieves and stalkers, with children particularly at risk [Sharratt & Usoro, 2003]. Of particular interest to our research is how the trust of the involved actors is assessed, analyzed and assured. One source of information needed to analyze and understand trust of actors in open online communities is the reputation of each actor.

FIRE - an acronym that is created from first two letters of the word '**fi**des', which is Latin for 'trust', and the first two letters of the word '**re**putation' - is a reputation-based model of trust that has been proposed as a means to support a common understanding of trust between

actors in open communities [Huynh, et al., 2004]. It provides an explicit representation of uncertainties, yet is only used to add weight to different nodes (actors) during the complete trust integration (creation) phase. It also employs a very simple approach for the aggregation of reputation information. The modelers enhance the performance of their model by separating different types of trust and reputation, but they do not reach the level represented in the trust model. The FIRE trust model integrates the following four different types of trust and reputation aspects (addressed in Section 2.3):

- *Interaction trust* resulting from past experience of direct interactions,
- *Role-based trust* defined by various role-based relationships between the actors,
- *Witness reputation* built from reports of witnesses about an actor's behaviour,
- *Certified reputation* built from third-party references provided by the actor itself.

The inter-relation between trust and reputation is not clear in this model and in particular, how the data on reputation is manipulated while analyzing trust of actors. Therefore, the function of evaluating trust may fail to account variations of reputation when the reliability of the actor's behaviour changes with time.

**Relevance to our research:** Although the trust model for open communities addresses the trustworthiness of individuals, the nature of the environment in which this model is applied have some similar characteristics to those of the VBEs – mainly, its virtual collaboration nature. Therefore different aspects related to analyzing trust of individuals in open communities, who can virtually interact without physically knowing each other, are relevant input for studying trust among the VBE member organizations, as addressed in Sections 2.2.

***iv) Taxonomy-based trust model for supporting an understanding of multi-agent systems (MAS)***

In recent years there has been a significant growth in the field of multi-agent systems in both research and practice. As applied to collaborative networks, an agent represents an organization rather than an individual or a system. One challenging issue in this field relates to the provision of support, which is necessary to facilitate cooperation between different agents and is fundamentally related to a computation of their reputations. Several researchers addressing MAS have discussed this challenge and suggested a number of reputation models that appear in the literature offering solutions to this problem. However, most of these solutions introduced specific concepts, terminologies and specific ways to represent reputation models and manipulation mechanisms [Korba & Song, 2003]. Consequently, it is difficult to achieve a "hypothetical understanding" of reputation evaluation among agents using different reputation systems [Pinyol et al., 2007]. To address this problem Pinyol et al., [2007] have proposed a trust model based on ontology (taxonomy) that aims to support agents to achieve the required level of common understanding of trust and, in particular, the mechanism they use for assessing reputations. A number of characteristics are considered for this purpose and included in the ontology, as illustrated in Figure 4.3. The key elements which the model examines are an agent's belief and its social evaluation, which are affected by a number of other subordinate elements, as shown in Figure 4.3. The model proposes a fundamental solution that can be implemented for exchanging the results of social evaluations of agents using different reputation models within the same multi-agent system paradigm.

**Relevance to our research:** Supporting the VBE member organizations within a network in achieving common understanding on concepts related to their trust, is as important as the creation of the trust itself. The taxonomy based model is developed to support agents with achieving common semantics on related reputation based systems. This model and its constituent concepts are consider in our research to understand how the concepts of inter-organizational trust need to be classified, and later on to be presented to organizations for the

purpose of enhancing their understanding of trust concepts as applied in the VBE environment as further addressed in Section 4.3.4.

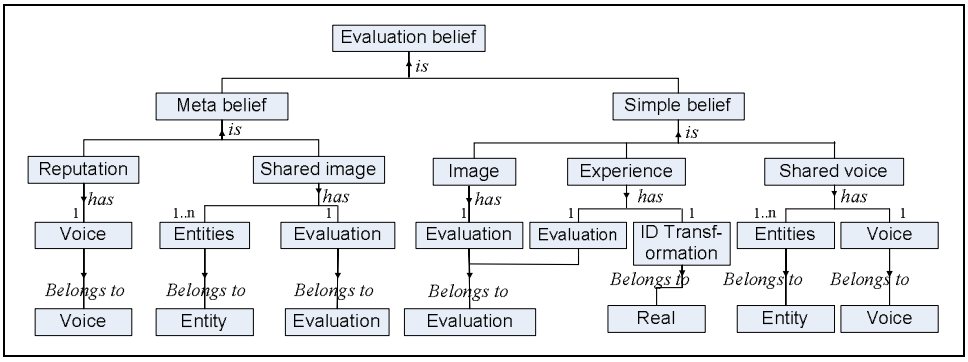


Figure 4.3: The taxonomy, membership relations, and components of evaluation of belief [Pinyol et al., 2007]

*Based on the concepts presented in [Pinyol et al., 2007] this figure shows the examination of agent's belief and social evaluation and their subordinate elements for supporting common understanding among agents.*

***v) Federation for Identity and Cross- Credentialing Systems (FiXs)***

This trust model is developed by FiXs [www.fixs.org]. The Federation for Identity and Cross-Credentialing Systems (FiXs) is a coalition of commercial companies, government contractors, and non-profit organizations whose mission is to establish and maintain a worldwide, interoperable identity and cross-credentialing network. This network is built on enforced security, privacy, trust, standard operating rules, policies, and technical standards. The FiXs network verifies and authenticates the identity of personnel seeking to enter the U.S. military installations and other government-controlled areas, as well as the commercial sites tied to the network. FiXs provides a trusted mechanism for federated identity infrastructure within and between public and private sector organizations with accuracy through the application of a so-called "Federated Trust Model". The network services supported by the trusted mechanism can be accessed worldwide, in remote or fixed environments, wired or wireless, and in real-time. A key component to the network integrity is its strong credential authentication and revocation processes, as governed by the FiXs operating rules.

The Federated Trust Model defines an underlying foundation that guides the common operating rules and legal procedures of the Federation of Identity and Cross-Credential Systems. It enables all participants and advisors to keep their existing security systems and policies intact, while strengthening their credentialing processes, in order to achieve balanced levels of trust within a shared infrastructure. The model is based on the concepts of community trust and brokered trust (Figure 4.4) [FiXs, www.fixs.org].

**Relevance to our research:** The trusted mechanism that supports organizations' access to network services, and the trust model which defines the common operating rules and legal procedures for collaboration, are the fundamental concepts applied to the establishment of trust among interacting actors who use the federated identity infrastructure. VBE Member organizations are typically in geographically dispersed locations. Therefore, the concept of federation introduced in this trust model helped us to understand and learn about how the analysis of trust among organizations can be performed when considering the need for interoperability among their systems. As such, the interoperability aspect of organizations is

analyzed, considering the level by which the organizations' information systems meet the following elements of the VBE: formulated policies, operating rules, security guidelines, specified architectures, etc. Furthermore, these concepts are applied in the thesis for better understanding of the need for sharing and exchanging information and knowledge between VBE member organizations and the influence of the results of these processes on inter-organizational trust relationships as addressed in Sections 2.4 and 2.5.

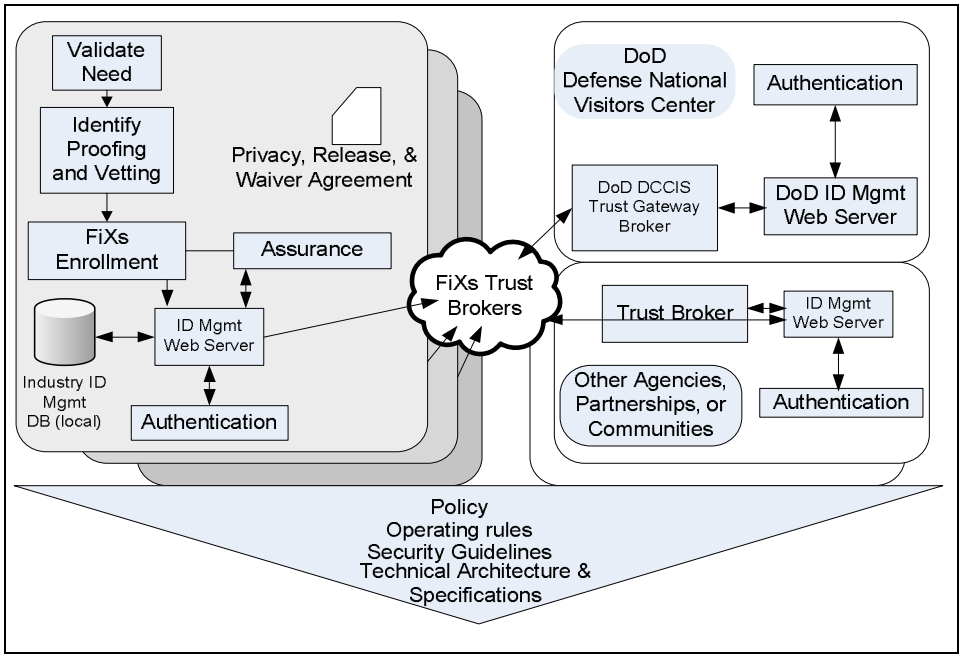


Figure 4.4: Trust model for the Federation of Identity and Cross-Credential Systems

*Based on the concepts presented in www.fixs.org, this figure shows components of a model supporting coalition of commercial companies, government contractors, and non-profit organizations whose missions are to establish and maintain a worldwide, interoperable identity and cross-credentialing network.*

***vi) Direct: A trust model for the VO creation process***

This model is based on reputation and is applied in the process of VO creation [Avila-Rosas & Luck, 2005]. As such, the potential partner organizations will decide to accept or reject an invitation for the VO on the basis of each other's reputations. The model also eases the process of assessing and selecting the most suitable set of network member organizations for a VO. The reputations are assessed on the basis of personal and mediated experiences by applying certain reputation systems. Information on reputations is based on what one party has said about another party over time, and the history of the interactions of these parties with others [Lucas, 2005].

Reputation systems have been addressed by a number of research and development projects. These systems are used in various applications, among others, in e-commerce to assess the trust of buyers/sellers, and in collaborative environments to assess trust of potential partners. As implemented in various systems, *reputation* is a function of the cumulative positive and non-positive ratings/opinions for an actor over the recent periods (weeks, months, years) related to how it is known and perceived by others [Resnick & Zeckhauser 2000].

Reputation systems are applied to analyze the collected reputation data and provide results about the subjective trustworthiness of actors for a particular purpose.

Despite the obvious usefulness of reputation and related concepts for collaboration, such as in supporting exchanging and transferring knowledge between organizations [Lucas, 2005], there are still some existing conceptual gaps in the current developed and applied models. Resnick and Zeckhauser [Resnick & Zeckhauser, 2000] have pointed out the so-called "*Pollyanna"* effect in their study of a larger set of reputation systems. In relation to this effect, it has been observed that there is disproportionately positive feedbacks from users and rare negative feedbacks which in turn makes the results from the analysis in most cases biased and do not represent the actual true picture [Rao, 2006].

**Relevance to our research:** One fundamental strategic goal of the VBEs is to support their member organizations to rapidly and efficiently configure VOs in response to brokered opportunities. A fundamental indicator for potential VO partners (organizations) is their trust level. As proposed in this thesis the main input data to the assessment of organizations' trust level is a set of their measurable fact-based data e.g. in relation to their performance (as addressed in Section 3.2.2). However, in some cases the performance data of organizations might not be up-to-date or some measurable data might be missing / incomplete. In such case, the organizations' reputation can be applied instead to indicate their actual trustworthiness subjectively. Thus our research has benefited from the presented concepts in this model as a fundamental input to understanding the process of complementing the rational analysis of trust in potential VO partners with some subjective trust analysis, if and when it is needed as addressed in Sections 2.3.4 and 2.3.5.

## 4.3 Modeling of trust relationships between organizations - The proposed approach

In order to accurately model trust relationships between organizations and to represent their related components, we have chosen to base the definition of our model of trust on the following three formalisms [Msanjila & Afsarmanesh, 2007b].

- *Ontology-based models* of trust relationships between organizations: to support organizations achieve and maintain common understanding about the fundamental concepts of inter-organizational trust.
- *Object-based models* of trust relationships between organizations: to address cardinalities of relationships between trust elements, which are used for the implementation of functionalities of the TrustMan system.
- *Record-based models* of trust relationships between organizations: to provide a rough relational database schema, and thus applied to the design of the database for organization's trust related data.

Although the models resulted by applying these three modeling formalisms constitute some similar parameters, each of these three models of trust relationship between organizations is developed to cover certain specific aspects and support our research in achieving different purposes related to development of organizational trust management system, as further addressed in Chapter 6.

A priori to modeling trust relationships between organizations, we have to identify and classify trust aspects and factors that need to be included in the models. A challenge is that of ensuring that the model incorporates and covers all basic and advanced concepts as perceived in the targeted domain through requirement analysis with the users of the environment. As

such, each designed conceptual modeling is correct and complete, while clearly not unique for representing the addressed concepts, entities, characteristics and their inter-relationships.

### 4.3.1 Main trust parameters for modeling trust relationships between organizations

Trust parameters that need to be included in the conceptual model of trust relationship between organizations have been divided into five main groups, namely: the *trust actors, time, level of trust, trust relationship, and trust elements*. Considering the brief definitions of these parameters as presented in Chapters 1 and 3, below we provide formalized descriptions for each parameter in order to enhance the understanding of the models of trust relationships among organizations, as presented later in this chapter.

i) *Trust actors: Trustor and Trustee:* The two parties in the trust relationship, namely the trustor organization and the trustee organization, are important when defining, modeling, and creating trust in collaborative networks. In general, a variety of factors might be required by different trustor organizations for assessing the level of trust in the same trustee organizations, even if the trustors have the same "objective" in establishing trust relationships. Therefore, it is important that both the trustor organization and trustee organization are distinctly represented in the model of their trust relationship.

ii) *Time: Past, Present and Future:* A trust relationship (and its intensity) between two organizations is an issue of time, which may differ today or tomorrow from how it was yesterday. In other words, an organization's level of trust is not static and may vary depending on changes in the set of trust criteria, the values of the trust criteria, involved trustor organizations, specific ratings of trust level, and so on. All of these factors, which have the potential of influencing changes in an organization's level of trust, are time sensitive. Thus time is an important factor, and must be properly addressed when modeling trust relationships between organizations in VBEs.

iii) *Trust level:* Trust level refers to the intensity of the level of trust for a trustee organization in a trust relationship, on the basis of an assessment of the values for a set of necessary trust criteria. Therefore, the trustee's level of trust is an important aspect to consider for each trust relationship between two actors. Accordingly, this aspect is considered in the model of trust relationship between organizations.

iv) *Trust relationship:* Generally, a relationship is a state of connectedness between people or organizations, or is a state involving a mutual association between people or parties. Trust relationship here refers to the state of connectedness between a trustor and a trustee, the intensity of which is characterized and based on the level of trust. In our modeling approach, trust relationship is the primary parameter of the trust model.

v) *Trust elements:* One important aspect of characterizing trust in VBEs is the identification of trust elements for various organizations. As addressed in Chapter 3, we have found that trust elements considered for organizations are not at the same level of abstraction and/or measurability. Through requirement analysis with users we have identified a wide range of trust elements as presented in Section 3.3. The identified trust elements are hierarchically-related, from abstract (non measurable) ones which represent the root and other high level nodes, to the measurable ones which represent the lowest leaf nodes in the hierarchy. Together these elements characterize the trust and trust relationships for organizations and their classifications represent the fundamental concept of inter-organizational trust, and in particular related to the assessment of trust level of organizations. Therefore, the models of

trust relationship between organizations must also capture and include all these aspects further as described in Section 4.3.2.

### 4.3.2 Object-based conceptual modeling formalism

In recent years, object-oriented modeling (OOM) has become the de-facto standard in early phases of software development in research environments. The current state-of-the-art for conceptual modeling is dominated by Unified Modeling Language (UML) which has been initiated and further stimulated by industry [Maciaszek, 2007]. With UML, Modeling can develop three kinds of models, namely the *static models, structural models, and transitional models*. In some cases the concepts represented in static models and structural models are combined to produce a more comprehensive design model. OOM constitutes the following seven modeling constructs:

- *Objects:* These are entities that have state and attributes, and they provide services when initiated, instantiated and executed. Modelers who are interested in making blocks as a way of representing the problem domain and specifically address the requirements analysis mostly use object concepts.
- *Classes:* These constructs provide a way to categorize objects with similar attributes or services. Classes form an abstraction hierarchy through 'is_a' relationships.
- *Attributes:* These are used to represent an object's state. Modelers use attributes as a means to specify the type, visibility and modifiability of each function and procedure in the class.
- *Relationships:* These define how one object is related to another object. Relationships can be classified as '*is_a'* classification relations, '*part_of*' relationships, and as having '*associations*' between classes.
- *Methods (functions and procedures):* These are the operations that all objects in a class can perform in order to provide the targeted output of the object when called on to do so by other objects.
- *Message Passing:* Provide a means for objects to invoke services that are provided by other objects.
- *Use Cases/Scenarios:* Provides a description on the sequences of messages exchanged between objects in order to facilitate the execution of a specific service.

The main aim of developing the model of a trust relationship between organizations, by applying object-based formalism, is to represent applied trust elements as objects that provide users with proper ways of studying cardinality of a relationship between objects modeled to represent those elements. For example, defining the cardinality of the relationship between an object which is representing a trust criterion and another object which representing a trust perspective. Figure 4.5 shows an objective-based model of trust relationship between organizations. In Figure 4.5, TR represents the trust relationships, TRO represents the trustor organization and TRE represents the trustee organization. Detailed definitions of the parameters defined in this model are introduced in Sections 1.3.2 and 3.2.

Understanding of relations among trust elements and the possibility to model these elements as objects, capturing the cardinality of the relationships among the objects, assist the developers in the process of implementing organizational trust management systems. As addressed in Chapter 6 modules developed for supporting the computation of trust level of organizations, using the TrustMan system, are implemented as objects in Java programming language.

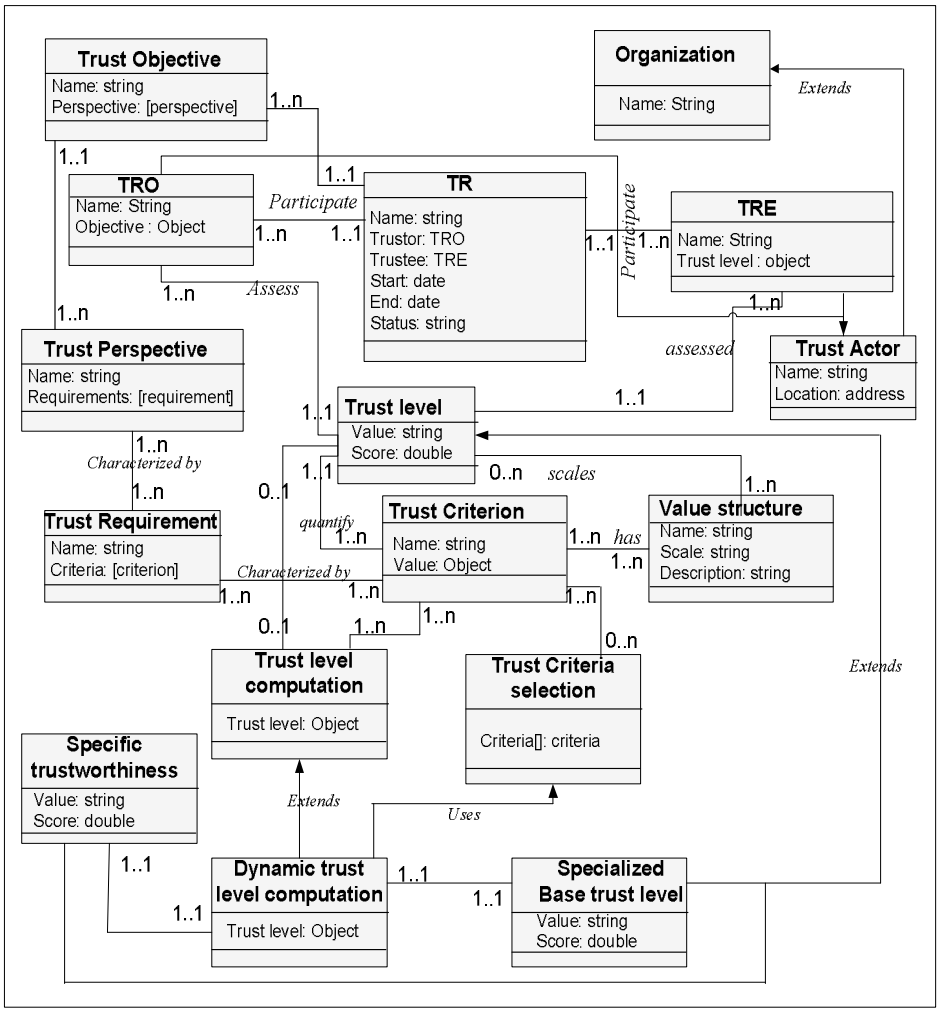


Figure 4.5: Object-based model of trust relationship among member organizations

*In this model, TRO refers to trustor organization, TRE refers to trustee organization and TR refers to trust relationship. This model shows classes and their inter-relationships representing various aspects of inter-organizational trust as characterized in the thesis.*

Therefore, the object-oriented model of the trust relationships between organizations is used to guide developers with the implementation of functionalities of the TrustMan system. The modules developed on the basis of this object-oriented model are also applied to classify the functionalities, on the basis of cardinalities of relationships among their implemented classes, into sets of integrated services.

### 4.3.3 Record-based conceptual modeling formalism

This formalism can be used to model trust relationships between organizations as records as inspired in the approaches for relational data modeling. In this modeling formalisms, a trust relationship (TR) is modeling as a record constituting five attributes, namely: trustor

organization (TRO), trustee organization (TRE), trust level of the trustee organization (TL), start date and status (equation (4.1)). The ***status*** indicates whether the TR is past, present or planned for future

$$TR = [TRO, TRE, TL, start\_date, status] \quad (4.1)$$

Trust level of the trustee (TL) is also modeled as a record constituting three attributes, namely: the trust perspective preferred by the trustor organization (perspective), the trust requirements for each preferred trust perspective, and trust criteria for each trust requirements (equation (4.2)).

$$TL = [Perspective, (requirements, (criteria))] \quad (4.2)$$

Furthermore, the trust criterion is modeled as a record of its value structure and value metrics (equation (4.3)).

$$Criteria = [value\_structure, value\_metric] \quad (4.3)$$

The three equations (4.1 to 4.3) together make the set of records constituting the record-based trust model for a single trustor organization to single trustee organization in a single trust relationship. If the respective trustor organization has multiple trust relationships with the same trustee organization, the attributes TL, start-date and status of the TR record (equation (4.1)) become repeating attributes. Repeating attributes are closed by parentheses and separated by commas. The representation of repeating attributes takes into account the fact that, although the actors are the same, it is possible that at different times there may be a different level of trust for each trust relationship between the trustor organization and trustee organization. While records for TL and criteria remain the same, the TR record changes as shown in (4.4).

$$TR = [TRO, TRE, (TL, start\_date, status)] \quad (4.4)$$

Furthermore, it is possible for a trustor organization to have many trust relationships with different trustee organizations (equation 4.5).

$$TR = [TRO, (TRE, TL, start\_date, status)] \quad (4.5),$$

A single trustee organization can also have at different times many trust relationships with different trustor organizations (equation 4.6). Moreover, these TR can have dissimilar intensity due to different levels of trust in the participating actors.

$$TR = [TRO, (TRE, (TL, start\_date, status))] \quad (4.6)$$

When the trustee organization has multiple trust relationships with different trustor organizations, the inverse of the records in equation (4.5) and (4.6) apply as shown in equations (4.7) and (4.8).

$$TR = [TRE, (TRO, TL, start\_date, status)] \quad (4.7),$$

$$TR = [TRE, (TRO, (TL, start\_date, status))] \quad (4.8)$$

A formalized record-based representation of trust relationships between actors when a trustor organization is simultaneously a trustee organization and probably with relation to different trustee organizations and trustor organizations respectively needs to be modeled. For this case, the following *record-based model* of trust relationship between organizations is developed, as presented in a diagrammatic form in Figure 4.6. Figure 4.6 shows four nodes N1 to N4, and

their trust related relationships, in which they may act as either a trustor or a trustee. In Figure 4.6 it is shown that the trustor TRO-1 has two trust relationships, one with the trustee TRE-2 and the other with the trustee TRE-3. However, the trustee TRE-2 is also the trustor as TRO-2 and it has two different trust relationships with the trustee TRE-4.

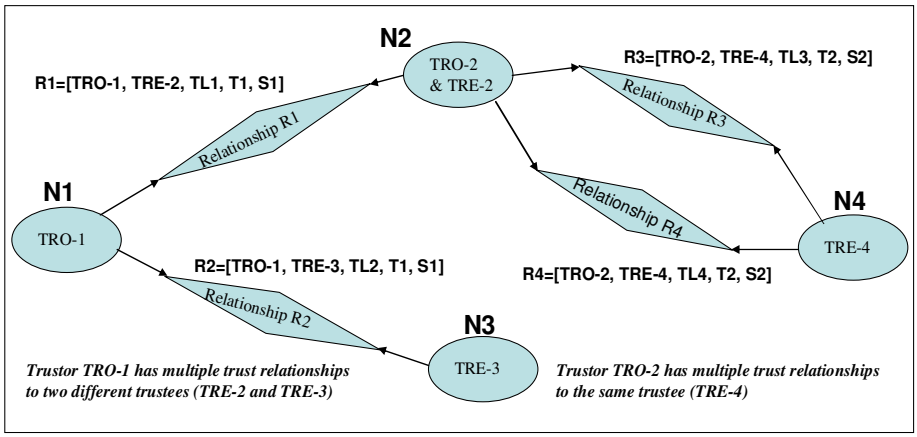


Figure 4.6: Relationship-based model of multiple participations among organizations

*Where TL represents trust level of the trustee organization, T represents time (start date), and S represents status of the relationship (past, present, future). This is a model of trust relationships among organizations in which the involved trustors and trustees are involved in more than one interaction at the same time.*

One of the most challenging and central tasks in managing the process of trust between organizations is managing the data that is required to support the assessment of the organizations' level of trust. A traditional approach for managing structured data is through maintaining a database. The main objective of data modeling in databases is to provide a data structure that adequately represents the real world and that can be processed efficiently by database management systems. Developing services supporting the management of data is an important part of the processes for managing inter-organizational trust. As a result, trust related data must also be correctly modeling and structured using some systems in order to enhance the effectiveness of its exploitation.

Most existing databases and database management systems follow a relational approach. In order to enhance the interoperability and sharing of data that is managed by the TrustMan system with the existing/legacy databases, the database that we developed also adopted the relational approach. Therefore, in our design and implementation of the system for managing trust related data for organizations, we have used the record-based models of trust relationship between organizations addressed above to define relational database schemas detailing the required records (types) and respective attributes (columns). Namely, based on the classification of trust elements as presented in Section 3.2, we have designed three different schemas: *schema for general data related to trust elements, schema for general organizational data, and schema for trust related data of organizations* (as further defined and addressed in Section 6.5.4).

### 4.3.4 Ontology-based conceptual modeling formalism

In information sciences and engineering, ontology refers to 'an explicit specification of a conceptualization', 'a theory or a system of concepts/vocabulary used as building blocks for information processing systems', and 'a representation of semantics of terms and their inter-relationships'. A VBE environment is characterized by its dynamic characteristics, such as its environmental features, objectives, member organizations, etc. New ontologies for VBEs will continuously emerge and existing ones will evolve. Development of a trust related ontology will also undergo the same life cycle processes [Afsarmanesh & Ermilova, 2007].

The effectiveness of an assessment of level of trust and the acceptability of its results is greatly influenced by the common understanding of trust between its involved parties, including trustor organizations, trustee organizations, VBE administrator organization, and other stakeholder organizations. One approach for supporting establishment of such an understanding of trust is by providing these parties with an ontology describing the concepts and terms used for the various elements, features, principles, mechanisms and software tools [Afsarmanesh & Ermilova, 2007a]. For the specific purpose of supporting such common understandings on trust, we have developed an ontology-based model of trust relationship between organizations classifying the taxonomical relations between trust elements (Figure 4.7). This ontology is described for VBE environments and included within the *Ontology Discovery and Management System* (ODMS) developed with the ECOLEAD project [Afsarmanesh et al. 2008].

Concepts related to the level of trust in organizations, inter-organizational trust relationships, different trust elements, and so on must also be understood well by all of the actors within a VBE. Therefore, the ontology-based models for trust relationships between organizations are also applied to the implementation of the TrustMan system.

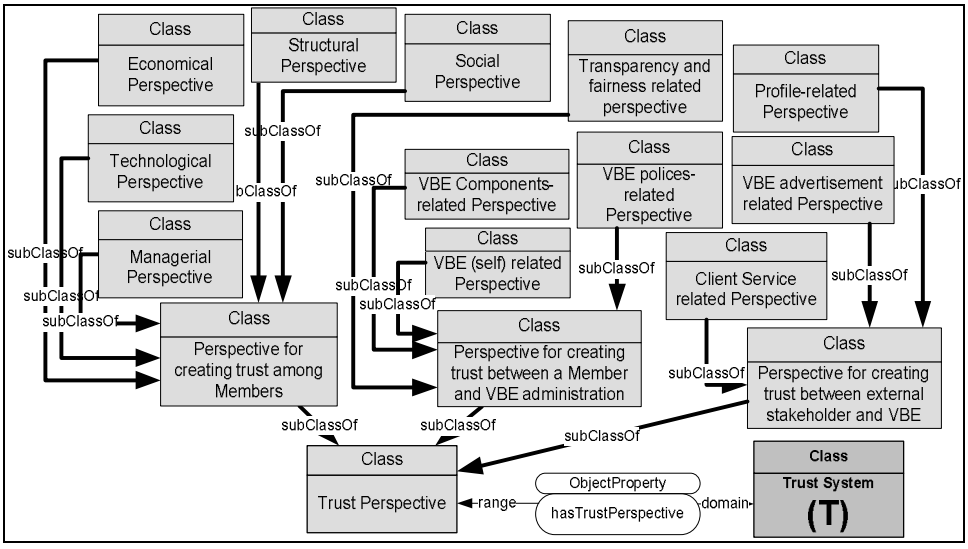


Figure 4.7: Ontology-based model of trust relationship between organizations

*This figure shows the taxonomy inter-relationships among various concepts and aspects representing the classes of trust elements that characterize trust relationships among organizations.*

## 4.4 Chapter discussion and conclusion

This chapterhas addressed the conceptual modeling of trust relationship between organizations as a means to contribute to the characterization of inter-organizational trust. It has presented three kinds of conceptual modeling formalisms, namely: *object-based, record-based and ontology-based formalisms,* where each one is also exemplified with some models for trust relationships between organizations.

Object- oriented paradigm assists system developers in addressing the complexity of a problem domain by considering the problem not as a set of functions that can be performed but primarily as a set of related and interacting objects. The modeling task therefore consist of specifying for a specific context, those objects (or the class that the objects belong to), and their respective set of properties and methods, shared by all object members of the class. This modeling approach also supports the analysis of cardinalities of relationships between the objects. On the basis of these concepts, an object-based model of trust relationship between organizations is applied in this thesis to designing and implementing modules/functionalities of organizational Trust Management System, as further addressed in Chapter 6.

Relational databases are the most commonly used type of data storage in research and practice. This is due, in large part, to the fact that the simplicity of their storage and access principles offers users greater efficiency. Also, the table-like structures map easily to most real-life data formats, such as forms and spreadsheets. Record-based models of trust relationship between organizations, developed on the bases of the concepts in relational data modeling, are presented in this chapter. These proposed models are applied here in designing a relational database schema for data related to trust in an organization. The designed schema is applied in developing a database for the TrustMan system as described in Section 6.5.4.

Effectiveness of assessment of the level of trust in an organization and the acceptability of its results is greatly influenced by the common understanding of trust concepts between its involved parties. Such parties in VBEs include: trustor organizations, trustee organizations, VBE administrator organization, and other stakeholder organizations. One approach for supporting the establishment of such understanding of trust concepts is by providing these parties with an ontology describing these concepts and the terms used for various trust elements, mechanisms for assessing trust level, and applied functionality offered by the software tools used for this purpose. This chapter has presented an ontology-based model of trust in VBEs between the participating organizations and other actors, in order to achieve a common understanding regarding these fundamental trust concepts.

In this chapter, we have addressed the main research question MRQ2. We have presented models of trust relationships between organizations that can be used to provide knowledge to different actors, in order to help them achieve better understanding of trust, such as gaining insight on trust related concepts, designing a database schema, or understanding relations among objects representing trust elements. An integrated overview of how all posed questions in this thesis that are addressed by different chapters is presented in Chapter 7.

Inter-organizational trust plays a key role in facilitating collaboration within VBEs. Therefore, better understanding of the concepts related to inter-organizational trust is necessary for creating successful collaborative networks of organizations. This chapter proposes models of trust relationships among organizations, constituting their related trust elements and inter-relations. As such, the chapter provides the stakeholders in VBEs' research and practice with a set of models to enhance the understanding and characterization of inter-organizational trust, as addressed in the thesis. These developed models are applied to the design and development of the organizational trust management system (TrustMan system) presented in Chapter 6.