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

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Chapter 6

Development of trust management system for VBEs

One obstacle to the configuration of VOs as well as the management of VBEs has been the difficulty in assessing the trust level of involved organizations. The assessment of trust level of organizations has been performed manually by trustors and in ad hoc manners, which is both time consuming and hardly produces accurate results. Consequently, formation of collaborative initiatives in form of temporary consortiums such as VOs has become more challenging and organizations are reluctant to work with each other. This chapter presents the development of services constituting the trust management system which is designed to support the management of trust among organizations required for VO creation in the VBE.


6.1 Introduction

This chapter presents the development of the Trust Management (TrustMan) system. It addresses the analysis, specification, architectural design and implementation aspects related to different steps for its system development. The TrustMan system is designed to assist the management of the VBEs (as addressed in Chapter 1), by handling tasks related to control and assessment of trust level of organizations within the VBE. TrustMan system is a subsystem of the so-called VBE management system (VMS), as further addressed in Section 6.2.

The remaining of this chapter is organized as follows: Section 6.2 presents the VBE management system and introduces its main subsystems. Section 6.3 introduces the main concepts relating to the TrustMan system and presents aspects regarding the implementation of mechanisms for assessing the level of trust in organizations. Section 6.4 presents the analysis and specification of the TrustMan system through its potential users and their requirements, as well as proposed functionalities and services. Section 6.5 presents the design of the TrustMan system and provides its “interoperability architecture” and its “four-layer componential architecture”. Section 6.6 addresses the implementation of the TrustMan system and its adaptation to industrial VBE networks. Lastly, Section 6.7 presents some conclusions and a summary of the concepts addressed in this chapter.
6.2 VBE management system

Collaboration among autonomous and geographically dispersed organizations is a process increasingly facilitated by advances in computer networks, support services, and related technologies. Collaboration among different sites is important for facilitating and leveraging various activities in societies, such as those related to innovation, scientific research, emergency and disaster management, and so on. As a result of intense research and development in this area, new specialized management systems for collaborative networks are now being developed. One challenging task in this process is the development of a system providing services for the management of the collaborative networks, such as the VBEs.

The management system in collaborative networks is a collection of services and functionalities supporting the framework of processes and procedures used by stakeholders during its life cycle, which ensures that the network can operate smoothly fulfilling all required tasks to achieve its objectives [Afsarmanesh et al., 2008]. The VBE management system shall perform the administrative tasks including the assignment of partner responsibility, maintaining a schedule for activities to be performed, as well as providing a set of tools to facilitate the implementation of actions and such scheduled activities; thus creating a productive and smooth VBE environment. Such a system is here referred to as the VBE management system (VMS). Thus the VMS serves the purpose of assisting the VBE administration in performing its tasks related to the management of the VBE, and its successful progression towards achieving its objectives.

6.2.1 VMS base concepts and motivation

Collaborative Networks (CN) have been established as an emerging new scientific discipline (Camarinha-Matos & Afsarmanesh, 2005). A number of specific forms of CNs can be currently observed in business practices and society. However, as new forms of CNs are emerging, innovative solutions are required to address the many challenges faced by collaborating partners, and in particular within VBEs.

A number of VBE networks (or similar such networks that share some characteristics with the VBEs) now exist worldwide, including the SwissMicroTech (Switzerland), the HELICE (Spain), the CeBeNetwork (Germany), and the IECOS (Mexico) (see their description in Annex C). Management activities of these VBE networks can be facilitated with certain semi-automated tools and services that aim to enhance the efficiency of performing VBE activities, such as reducing the required resources, time and costs. However, the existing management systems in currently operational VBEs are limited and do not properly support their requirements capturing all characteristics of VBEs. One such characteristic is the involvement of organizations which are heterogeneous in many aspects (e.g. their structural, componential, functional and behavioral aspects), and autonomous in their decision making, systems of values, and interests in the market and society (Afsarmanesh, et al. 2007). A number of sub-systems need to be developed for the VMS, as described in the next section. For example, the VMS is aimed to assist the VBE administration with performing the following tasks:

- Managing the profiles and competencies related to the VBE member organizations, to VOs, and to the VBE itself
- Management and discovery of the ontology for the VBE environment
- Assessing, managing and balancing the trustworthiness of the organizations in the VBE
- Collecting/managing information related to the performance of organizations within the VBE
- Supporting the acquisition of new members and managing the VBE member structure
- Managing the collective assets (data, best practices, software, etc.) in the VBE and VO
- Supporting the processes of decision making based on some collected data in VBEs.
It is necessary to note that the need for addressing the above specific VMS components is identified through extensive requirement analysis and road-mapping work carried out in previous research relating to the EC-funded project VO-map (Camarinha-Matos, Afsarmanesh, 2003). The fundamental requirement analysis and road-mapping results were achieved together, and/or in consensus with a large group of field experts involved in this initiative, and were further validated and approved by the CN community of experts, including academic, research and industry visionaries.

### 6.2.2 VMS subsystems

As characterized and developed for VBEs in the ECOLEAD project (as addressed in Section 1.7), the VMS constitutes a number of subsystems, as shown within Figure 6.1, and briefly summarized in subsequent paragraphs. Please note that Figure 6.1 also expounds the required interactions between these subsystems. The VMS system developed in ECOLEAD constitutes the following seven main subsystems, (Figure 6.1) [Afsarmanesh, et al., 2008]: (i) VBE Membership and Structure Management System (MSMS), (ii) Profile and Competency Management System (PCMS), (iii) Ontology Discovery Management System (ODMS), (iv) Trust Management system (TrustMan), (v) Decision Support System (DSS), (vi) VO Information Management System (VIMS), and (ii) VO Creation Services (VCS)

i) **VBE Membership Structure Management Systems**: Acquisition and registration of new member organizations in VBE networks is particularly related to assessing their suitability in the VBE. Collection and analysis of the applicants’ information as a means to ascertain their suitability in the VBE has proved particularly difficult. This subsystem provides services which support the integration, accreditation, disintegration, rewarding, and categorization of members within the VBE. In particular, it addresses functionalities for registration and rewarding of members, and management of their roles and rights.

ii) **Profile and Competency Management Systems**: Due to the dynamics of VBEs, caused by the daily changes in customers’ demands and all other aspects of the market and society, a VBE must have the needed data to be able to quickly analyze its members’ competencies against emerging opportunities. The high level of dynamism in medium and large size VBEs means that the VBE administration is unable to obtain and analyze up-to-date competency information on all of its members. There is thus a need for ICT-based submission and processing procedures for members’ profiles and competencies. PCMS provides services that support the creation and maintenance of profiles and competencies of all VBE member organizations, of the collective VBE competencies, and of the VOs registered within the VBE.

iii) **Ontology Discovery Management Systems**: In order to systematize all VBE-related concepts, a generic/unified VBE ontology needs to be developed and managed. The ODMS system provides services for the manipulation of VBE ontologies, which is required for the successful operation of the VBE and its VMS. The services designed for ODMS aim to achieve the following main objectives: (1) providing a common understanding of the VBE-related concepts for all VBE actors, (2) facilitating the reusability of knowledge that has been accumulated in one VBE with that of another VBE, (3) providing the formal classification of the knowledge for VMS subsystems (e.g. competency) in order to facilitate the knowledge processing in VBEs by software, and (4) supporting knowledge interoperability both intra-VBE (to support varied forms of collaboration), and inter-VBEs (through sharing of the unified models of knowledge).
iv) **TrustMan system**: The TrustMan system is designed to support the VBE administrator and other stakeholders in the VBE with handling tasks that relate to both balancing the levels of trust in organizations in the VBE as well as assisting with the assessment of organizations for VO partner selection process. The TrustMan system is addressed in the remaining sections in this chapter.

v) **Decision Support Systems**: Decision-making within enterprises has been challenging. The decision making process in a VBE needs to involve a number of actors whose interests may even be contradictory. The DSS has three components that support the following operations related to decision-making within a VBE: Warning of an organization’s lack of performance, Warning related to the VBE’s competency gap, and Warning of an organization’s low level of trust.
♦ The tool for the lack of performance warning supports the VBE administrator to analyze the progressive performance of member organizations, and to send a warning message to a specific organization when its performance has fallen beyond a certain specified threshold.

♦ The tool for competency gap analysis is designed to support the VBE administrator in discovering weak points and missed opportunities due to a lack of competencies needed in the market/society, but missing in the VBE. It is based on two important elements: (1) the definition of the VBE’s strategic competency plan, and (2) an analysis of the missed collaboration opportunities in the market. The strategic competency plan targets the expected VBE competencies to reflect on the actual competencies available in the VBE at a certain point in time. The aim of this analysis is however to compare the required competencies in the market versus those available in the VBE. This approach enables the missing competencies in the VBE to be identified, which facilitates the definition of the measures that need to be taken in order to acquire and attract these competencies.

♦ The tool for low trustworthiness level warning supports the VBE administrator in managing and balancing the levels of trust in organizations by analyzing their progressive trustworthiness. This tool provides a scheduled calculation of the trust level by executing the service for assessing trustworthiness of organizations, provided by the TrustMan system. Based on progressive results, this tool will send a warning message to organizations whose trust level has fallen beyond the specified threshold.

vi) VO Information Management Systems: We can deduce from the underlying concepts of VBEs and VOs, the benefits for a VBE of incorporating experiences from previous VOs into the creation of new ones. Developing thorough processes and guidelines on how to use this information in the process of VO creation is dependent on the VO Creation Framework. However, the management and provision of VO related data is subject to the VIMS. Thus, the functionalities supported by VIMS provide mechanisms for storing information about newly created VOs and dissolved VOs within the VMS data-structure.

VO-related information will be needed by the VO planner as a repository of experiences with certain partners and combinations of partners in the past. The VO initiator will need this information as input in the decision on which of the two or more competing partners are to engage in the VO. The VIMS comprises the functionalities of (i) the Registration of Created VOs Service, and (ii) the Management of VO Inheritance Information.

vii) VO Creation Services: The potential to rapidly form a VO, when triggered by an identified business collaboration opportunity and specially tailored to the requirements of that opportunity, is the emerging solution – particularly for SMEs – and a survival mechanism in face of market turbulence (Camarinha-Matos, et al., 2005). The same approach is, however, spreading and also becoming appealing in non-business-oriented domains and contexts. Nevertheless, agility in the configuration of VOs as mission/goal-oriented collaboration networks necessitates an a priori preparedness of organizations, which takes time and effort and is nowadays supported through the pre-existing VBE.

Providing services for supporting the configuration of a VO, when an opportunity is brokered is now amenable, considering the current market trends and requirements. VO creation services support the opportunity brokers and VO planners with handling the tasks related to the configuration of new VOs. In ECOLEAD these services are provided through the following four tools:

♦ Collaboration Opportunity Identification and Characterization (coFinder): This tool assists the opportunity broker to identify and characterize a new Collaboration Opportunity (CO) in the market/society that will trigger the formation of a new VO within the VBE. A collaboration opportunity might be external, initiated by a customer and brokered by a VBE member that is
acting as a broker. Some opportunities might also be generated internally, as part of the VBE’s development strategy.

♦ CO characterization and VO’s rough planning (COC-plan): This tool supports the planner of the VO with developing a detailed characterization of the CO needed resources and capacities, as well as with the formation of a rough structure for the potential VO, therefore, identifying the types of required competencies and capacities needed from organizations that will form the VO.

♦ Partners search and suggestion (PSS): This tool assists the VO planner with the search for and proposal of one or more suitable sets of partners for VO configurations. The tool also supports an analysis of different potential VO configurations in order to select the optimal formation.

♦ Contract negotiation wizard (WizAN): This tool supports the VO coordinator to involve the selected VO partners in the negotiating process, agreeing on and committing to their participation in the VO. The VO is launched once the needed agreements have been reached, contracts established, and electronically signed.

6.3 Trust management system

Establishment of trust relationships between organizations has proven to enhance the cooperation among organizations involved in VBEs and their collaboration within the VOs. However, the main obstacles in establishing trust relationships, as described in the previous chapters stems from the lack of a common definition for trust and trust elements. Consequently, the assessment of organizations’ level of trust and the creation of trust between organizations are quite challenging. In practice, organizations individually evaluate the trustworthiness of others both manually and in an ad hoc manner, which is both time consuming and highly unlikely to produce accurate results. This section presents an approach and a system for Trust Management, which assists the management of VBEs, and is a part of its VMS. Based on the multi-criteria and customizable trust models presented in Chapters 4 and 5, this chapter defines a TrustMan system that on one hand combines the introduced models and approaches, and on the other hand provides services for supporting processes related to the management of trust between organizations within VBEs.

6.3.1 Mechanisms for assessing trust level of organizations

Perceptions of trust have corresponded with both the nature of the purpose of its application, as well as the actors involved. Thus, the purposes for establishing trust differ among different practices. For each specific practice in which a particular group of actors is involved, trust is interpreted and perceived differently. In this thesis, trust aspects for VBEs are classified into five perspectives: Technological (Tech), Social (Soc), Structural (Str), Managerial (Man), and Economical (Eco), as described in detail in Chapter 3. Furthermore, in order to address the differences in trust perceptions, a rational trust level assessment approach is required for VBEs to both assist the measurement of trust level of organizations and reasoning of the results, as addressed in Chapter 5.

In order to “rationally” assess the level of trust in organizations, a series of fact-based trust criteria are applied, as addressed in Chapter 5. Using an empirical study of running VBE networks, as well as a survey of past research, our research has identified a substantial number of measurable criteria (trust criteria) that act as indicators of trust assessment [Msanjila & Afsarmanesh 2007c], as further described in Chapter 3. It has also revealed that the influence of a trust criterion on the level of trust can be either positive or negative, depending on its behaviour in the environment. Furthermore, the behaviour of each trust criterion changes over time and causally influences other criteria. Causal influences can be studied by applying
concepts from system dynamics [Kirkwood, 1998], and the results of a causal analysis can be visually represented in a so-called “causal diagram”. Such results can also be translated into mathematical equations that reflect the inter-relations among trust criteria [Msanjila & Afsarmanesh 2007c]. The formulated equations comprise the base for the mechanisms that have been designed in the TrustMan system for assessment of the level of trust in organizations [Msanjila & Afsarmanesh 2007a]. As implemented in the TrustMan system, basically, mechanisms to calculate the final comparative trust score for an organization is formulated as the computation of an average of weighted scores of all trust perspectives (equation 6.1) where the weight is between 0 and 1, and the total weights applied for all parameters is 1. The following abbreviations are used in all subsequent equations: TL (trust level), S (score), per (trust perspective, i.e. Tech, Soc, Str, Man, and Eco, all described in Section 3.3), IF (intermediate factor), W (weight), and Avg (average).

\[
TL = \text{Avg}[(W_{\text{Tech}} * S_{\text{Tech}}), (W_{\text{Soc}} * S_{\text{Soc}}), (W_{\text{Str}} * S_{\text{Str}}), (W_{\text{Man}} * S_{\text{Man}}), (W_{\text{Eco}} * S_{\text{Eco}})] \cdots (6.1)
\]

The weights of parameters used in the equations are dynamically specified by the trustor organization depending on its trust objective during the assessment of trust level (See section 6.6.1, Module number 11). If these weights are not specified by the trustor then the TrustMan system assumes uniform weights for all parameters in each equation. The score for each trust perspective is calculated as a weighted average of the score for all intermediate factors as shown in equation (6.2).

\[
S_{\text{per}} = \frac{1}{n} \sum_{i} W_{\text{IF}_i} * S_{\text{IF}_i} \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots (6.2)
\]

Where “n” refers to the number of defined intermediate factors for the trust perspective

The score for the intermediate factors is calculated as a function of trust criteria and known factors as shown in equation (6.3). These equations are formulated from the results of causal analysis as addressed in Chapter 5.

\[
S_{\text{IF}} = f[\text{trust criteria, known factors}] \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots (6.3)
\]

### 6.3.2 Approach for developing the TrustMan system

Development of TrustMan system follows standard phases of the software life cycle, including: (1) system analysis, (2) system design, (3) system implementation, (4) system operation and (5) system maintenance as described in [Maciazsk, 2007]. These phases [Maciazsk, 2007] are normally performed sequentially, where the output of each phase, is used as the input to the next phase, as visualized in Figure 6.2 and briefly addressed in this section:

**Phase 1 – System analysis**: This phase focuses on aligning business processes with system processes when developing services to support potential tasks. Analysis related tasks are performed by two types of experts, namely, the business analyst and the system analyst. In this phase the first task is the identification of potential users of the system as well as activities/processes (user requirements) that need to be supported with services. Next, the identified user requirements which need some automated solutions (services) are used during the process of system specification to capture functionalities and services, input data and output data. Finally, results are documented in a so-called system requirement document which is the output of this phase and input to the next phase. The analysis and specification of the TrustMan system is addressed in Section 6.4.
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Figure 6.2: Phases in the Software life cycle

Based on the concepts in [Maciaszek, 2007] this figure shows the tasks which were performed during the development of TrustMan system.

+ **Phase 2 – System design:** This phase focuses on designing models and architectures of the intended system. Tasks related to system designing performed by the **system designer** are: (1) Defining internal components of the system, (2) Defining components supporting external interactions, (3) Developing the system architecture and (4) Designing user interfaces for human and remote-system users. The output of this phase is a well documented “**system design**” presenting system architectures and models. The document is used as input to the next phase to guide the implementation of functionalities and services. The design of TrustMan system is addressed in Section 6.5.

+ **Phase 3 – System implementation:** This phase focuses on the implementation of the system including: installing the platforms and coding of custom-written components. Development related tasks that are performed by the **system developer** are: (1) Coding the required modules and components, (2) Testing developed components, (3) Validating and verifying functionalities, (4) Compiling the system by integrating the separately developed components, and (5) Deploying the system to the real running environment. The output of this phase is the developed system (prototype) and its documentation which together are used as input to the next phase (system operation). The implementation of TrustMan system is addressed in Section 6.6.

+ **Phase 4 – System operation:** This phase focuses on handing the system (or take ups when the system is a prototype) to the customer (potential users) ready for running the system at the business site. At early stages of this phase all parties participated in the entire process of developing the system are involved, namely: the developers, the system analysts, the business analysts and the customers (users). If some faults happen while the system is operating then the next phase – system maintenance – starts. The operation (the take-ups) of TrustMan system is briefly addressed in Section 6.6.

+ **Phase 5 – System maintenance:** This phase focuses on the modification of the system, among others: to correct some faults, to improve performance, or to adapt the system to a changed environment or changed requirements. When a major modification is needed such as implementing a new functionality whose design already exists the third phase (system implementation) is repeated. If there is no design for the needed major modification or a new system need to be developed then the software life cycle is re-started. This phase is realized by commercial and business systems and not by prototypes. Prototypes are developed for the purpose of testing or verifying some features of a concept or commercial system that might be
developed in the future. Therefore, the TrustMan system did not undergo this phase because it is developed as a prototype. Nevertheless all new requirements that emerged during the trial and take-up phases of “TrustMan prototype” by industrial VBEs were addressed accordingly, and thus this prototype has gone through some needed maintenance.

6.4 Analysis and specification of the TrustMan system

This section addresses the analysis and specification stages of TrustMan system by: identifying and classifying its potential users, and defining the roles and rights of each user. The section also addresses the specification of functionalities and services of the TrustMan system.

6.4.1 Specification of system users and user requirements

Identification of users of the TrustMan system is based on the analysis of potential stakeholders for the three general trust objectives, as presented in Section 3.3, regarding the creation of inter-organizational trust within the VBE, namely:

♦ Trust between VBE member organizations: This trust objective addresses the assessment of the level of trust in organizations and the establishment of their trust relationships for different purposes, such as smoothing cooperation in the VBE, and enhancing collaboration in VOs. The potential stakeholders for this trust objective are: VBE administrator, VO planner, VBE member organizations, and VBE membership applicants. Requirements for the organizations related to this trust objective are described in Table 6.1.

♦ Trust between a VBE member and the VBE administration: This trust objective addresses the creation of trust in a VBE member organization towards the VBE administration, as a means to: enhance the commitment of the member to the VBE, ease managerial tasks, attract new member organizations to the VBE, and so forth. The potential stakeholders for this trust objective are: VBE administrator, VBE member organizations, and VBE membership applicants. The user requirements for the organizations related to this trust objective are described in Table 6.1.

♦ Trust between external stakeholders and the VBE: This trust objective addresses the creation of trust in external stakeholders towards a VBE, i.e. organizations that have been invited to become members or customers that wish to provide opportunities. The potential stakeholders for this trust objective are: VBE administrator, and external stakeholders (customers and invited organizations). User requirements for the organizations related to this trust objective are described in Table 6.1.

Five user groups are classified on the basis of these three general trust objectives. This classification is based on: each group’s respective user requirements that need to be supported by the system, the rights for each user within the system, and the roles that these users will play in addressing a specific trust objective. These five User Groups (UG1 to UG5) and their respective user requirements are presented in Table 6.1.

Table 6.1: Identification and classification of users of the TrustMan system

<table>
<thead>
<tr>
<th>User group</th>
<th>User roles &amp; rights</th>
<th>User requirements (UR)</th>
</tr>
</thead>
</table>
| UG1: VBE administrator | Highest administrative rights and can view, execute, modify all services | 1. Assessing the trustworthiness of membership applicants and VBE member organizations.  
2. Defining, authorizing and assigning rights to other users.  
3. Supporting other users, such as the VO planner, in evaluating the specific trustworthiness of trustee organizations for certain purposes.  
4. Managing the trust related data in the system. |
### User requirements (UR)

<table>
<thead>
<tr>
<th>User group</th>
<th>User roles &amp; rights</th>
</tr>
</thead>
<tbody>
<tr>
<td>UG2: VO planner</td>
<td>Limited administrative rights and can view and execute some services</td>
</tr>
<tr>
<td>UG3: VBE member</td>
<td>Normal user rights and can manipulate its own records</td>
</tr>
<tr>
<td>UG4: Membership applicant</td>
<td>Basic user rights and can submit trust related data</td>
</tr>
<tr>
<td>UG5: External stakeholders</td>
<td>Guest rights and can access public information only</td>
</tr>
</tbody>
</table>

- 5. Updating the list of trust criteria in the system.
- 6. Viewing the trust criteria that are used in the system.
- 7. Selecting specific trust criteria from the VBE pool of trust criteria.
- 8. Applying the selected trust criteria to evaluate specific trustworthiness of potential VO partners.
- 9. Accessing its base trust level records
- 10. Updating its trust related data
- 11. Viewing the trust criteria that are used in the system.
- 12. Submitting trust related data as a requirement to the analysis of its membership application
- 13. Supporting customers to analyze trust of VBEs and thus trusting those VBEs for purchasing their products and services.
- 14. Supporting invited organizations that want to become members in the VBE to analyze the trust of that VBE in relation to their businesses and possible benefits.
- 15. Supporting guests to access the basic information related to trust of the VBE.

In addition to the above identified and classified users of TrustMan system, another potential user is the **trust expert**. This is a specialized user which needs TrustMan functionality to support tuning the TrustMan system to match the requirements, such as the introduction of new trust criteria, disabling some refused trust criteria from the general set of trust criteria for VBEs, etc.

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**Figure 6.3: User rights hierarchy accessing TrustMan system**

These classifications represent different groups of user organizations with the same access rights. The hierarchy also represents access rights to the trust information that decreases downwards.
6.4.2 Specification of functionalities and services

In this section we address the specification of functionalities and services that shall be provided by TrustMan system. These specifications are based on the analysis and classification of user requirements as presented in Section 6.4.1.

A. Specification of required functionalities for the TrustMan system

Design of the TrustMan system, as addressed in Section 6.5, is based on the service oriented architecture (SOA) and in particular the web service technology. Accordingly, the specified functionalities are referred to here as services (referred to as “S” in table below). The system provides seven integrated services as described in Table 6.2 to support all user requirements as presented in Table 6.1.

<table>
<thead>
<tr>
<th>S</th>
<th>Service name and description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>For assessing the base trust level of organizations: This service supports the assessment of trust level of an organization applying the set of base trust criteria, for two main purposes, namely: supporting the periodic assessment of base trust level of member organizations and supporting the one-time assessment of base trust level of a membership applicant. This is mainly a VBE administrative service and it is accessed by the VBE administrator. The service also supports member organizations’ assessment of their own base trust level. This service addresses user requirements 1 and 9 (Table 6.1).</td>
</tr>
<tr>
<td>S2</td>
<td>For evaluating the specific trustworthiness of organizations: This service supports the trustor organization (VBE administrator, or VO planner) to evaluate the specific trustworthiness of an organization for a specific trust objective, such as inviting a VBE member to participate in a VO, appointing a VBE member to become a VO coordinator or the VBE administrator. The evaluation of specific trustworthiness can be done at any point in time, such as the current time. Furthermore, the evaluation can be used to forecast trustworthiness for future collaborations. This is an administrative service and is thus accessed by the VBE administrator and the VO planner. This service addresses user requirements 3, 6, 7 and 8 (see Table 6.1).</td>
</tr>
<tr>
<td>S3</td>
<td>For establishing trust relationships between organizations: This service supports an organization, based on its user rights, to access trust related data and decide regarding the suitable information to provide to other organizations in order to create trust. The challenge here concerns the provision of required information to create trust between organizations aimed at supporting the establishment of trust relationships. Therefore, it is related to five aspects, namely: “who”, “when”, “why”, “what” and “how” (as further addressed in details in Section 2.4). However, certain information that is stored in the system might be too strategic; as a result of which the owner organizations will be unlikely to allow it to be publicly accessed. In order to support this requirement, the access to trust related information is categorized as: (1) Public access – any organization inside or outside the VBE may access the information, (2) Restricted access – any VBE member organizations may access the information, and (3) Protected access – only the VBE administrator and the owner organization itself may access the information. This is a semi-administrative service that can be accessed by the VBE administrator and VBE member organizations. This service addresses user requirements 5, 6, 9, and 11 as shown in Table 6.1.</td>
</tr>
<tr>
<td>S4</td>
<td>For managing trust related data: This service supports three kinds of users, namely:</td>
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</tbody>
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<table>
<thead>
<tr>
<th>S</th>
<th>Service name and description</th>
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<tbody>
<tr>
<td></td>
<td>VBE membership applicants, VBE member organizations, and the VBE administrator, for different purposes. The VBE membership applicant will use this service to submit its own trust related data in order to facilitate the evaluation of its qualifications to join the VBE. The VBE member organizations will use this service to update their own trust related data. The VBE administrator will use this service to manage all trust related data in the system, i.e. to ensure that it is up-to-date, valid and extracted from a reliable source. It service addresses requirements 4, 5, 10, 11, and 12 (see Table 6.1).</td>
</tr>
<tr>
<td>S5</td>
<td>For creating trust in the VBE: This service supports external stakeholders (customers and invited organizations) to create trust to the VBE establishment for different purposes. The external stakeholders need to access information that will persuade them of the trustworthiness of the VBE in relation to their businesses. The service also helps customers to build trust in the VBE in order facilitate business transactions, such as opportunity bids, payment procedures, and so forth. This service addresses user requirements 13, 14, and 15 as shown in Table 6.1.</td>
</tr>
<tr>
<td>S6</td>
<td>For managing the assessment mechanisms: As shown in Section 6.3.1, the equations applied for the development of mechanisms for assessing level of trust in an organization incorporate some weights for the included trust criteria and the known factors. These weights may be changed from time to time when it is necessary. This service assists the VO planner, VBE administrators and trust experts in adjusting these weights when necessary. This service addresses the user requirements 2, 4, 6, 7, and 8 (see Table 6.1).</td>
</tr>
<tr>
<td>S7</td>
<td>For analyzing an organization’s trust-level history: This service supports VBE administrator to track the history or evolution of trust level of an organization. It has a mechanism that triggers the service for assessing base trust level for all organizations in the VBE periodically (such as every six-months). The service then stores the results in the TrustMan database, the user can retrieve both the trust level history of specific organizations for a given period of time, and/or perform some analyzes such as identifying the weak or strong organizations. As presented in Section 6.2.2 this service is invoked by DSS (Decision Support System) tool which is a subsystem of VMS. Further analysis of the evolution of trust level of an organization is supported by DSS.</td>
</tr>
</tbody>
</table>

B. Specification of input data and its sources:
The input data used in the process of assessing trust level of organizations are the values of defined trust criteria for the organizations. The main sources of input data (organizational data related to trust) as addressed in this thesis are twofold: (1) Data submitted by each VBE membership applicant and (2) Performance data of organizations gathered by VBE in relation to the organizations’ participations in VOs and other VBE related activities.

C. Specification of output data and its presentation:
The output produced by the services for assessing trust level of the organization and evaluating its specific trustworthiness is the “level of trust” expressed qualitatively, using the scales provided by the Trust-Meter, as shown in Figure 5.1. Qualitative representation of trust level of an organization is based on the interpretation of scores computed by the TrustMan system (as exemplified in Table 5.1), namely: the Strongly less trustworthy, Less trustworthy, Average trustworthy, More trustworthy and Strongly more trustworthy.
### 6.5 Designing the TrustMan system

Based on the specification of services presented in Table 6.2, this section presents the design of the TrustMan system, addressing its two architectures, namely: the interoperability architecture, and the four-layer componential architecture. It also presents the design of its user interfaces and the database.

#### 6.5.1 Interoperability architecture of the TrustMan system

TrustMan system is one of the subsystems constituting the VBE management system (VMS) as presented in Section 6.2. In order to provide the required services accurately and comprehensively, the TrustMan system interacts with others sub-systems as shown in Figure 6.4 for four main purposes, namely (a) acquiring the trust related data, (b) providing results of the trust level assessment, (c) accessing basic services provided by the ICT-Infrastructure (called ICT-I), and (d) supporting human user access. The interoperability architecture of TrustMan system is designed to guide developers in implementing the needed modules for supporting these four kinds of interactions. Please note that the internal components of the system (the area indicated with dashed line in Figure 6.4) are discussed in Section 6.5.2.

External interactions, as further described below, are supported by a number of internal components of TrustMan system that are grouped into three categories, namely the component for: (1) User right control, (2) Services choreography, and (3) Results provision.

- The components for user right control provide functionalities for authorizing users (both human and system users) that wish to access the TrustMan system. For the authorized users, these components also provide functionalities for classifying the services on the basis of the user rights as well as providing access to those services that each user is allowed to view or execute (such as public, restricted or administrative services).

- The components for services choreography provide internal mechanisms and/or functionalities to organize the order and time for the execution of a number of services in response to each received user’s request.

- The components for results provision organize and provide proper responses to requests received by the system, such as returning specific results for the successful requests, or returning negative response for the rejected requests.

As described earlier in this section, the TrustMan system supports four types of external interactions, indicated as (a), (b), (c) and (d) in Figure 6.4, as are described below.

#### (a) Interactions for assisting the acquisition of trust related data

Two sub-systems, namely the Membership Structure Management System (MSMS) and the Performance Data related Management System (PDMS), interact with the TrustMan system for the purpose of submitting trust related data as addressed below.

- Interaction with MSMS: One fundamental piece of information needed by the VBE administration in order to decide whether to accept a VBE membership applicant organization is its base trust level. The MSMS interacts with TrustMan system so as to facilitate the applicant’s submission of the trust related data.

- Interactions with PDMS: Organization’s data related to trust must be kept up-to-date and thus needs to be continuously updated. The PDMS interacts with the TrustMan system to assist the VBE member organizations with updating the trust related data on the basis of the organizational performance that is gathered in relation to their participation in
different activities. The PDMS constitutes a set of information management systems that support the management of VO related information and inheritance, and the VBE activities related performance data.

![Diagram of TrustMan system](image)

**Figure 6.4: Interoperability architecture of TrustMan system**

This figure shows other sub-systems of the VMS that will interact with the TrustMan system. It also indicates different purposes of interactions (with arrows) as described below in this section.

**b) Interactions related to accessing organizations’ records of trust level**

Three VMS subsystems invoke the services provided by the TrustMan system, namely: Membership Structure Management System (MSMS), Decision Support System (DSS), and Partner Search and Suggestion (PSS), as addressed in Section 6.2.1. These VMS subsystems need to invoke some services provided by the TrustMan system in order to access the information about organizations’ level of trust. The level of trust in an organization is used as input by the client systems to provide the required services to their respective users.

- MSMS will invoke the service for assessing the base trust level of an organization in order to support the VBE administrator analyze whether the applicant organization meets the required minimum level of trust in an organization within the VBE.

- DSS supports the VBE administrator to analyze the evolution of the level of trust in an organization for a past period of time. In order to support the analysis of the evolution of organization’s level trust, the DSS periodically invokes the services provided by the TrustMan system for assessing the organization’s base trust level. Therefore, these organizations whose trust level is continuously deteriorating can be alerted and advised on how to enhance their trustworthiness.
PSS supports the VO planner to select suitable VO partners among the VBE members. One key activity during the selection of such VO partners is the evaluation of their specific trustworthiness. The PSS interacts with the TrustMan to support the VO planner with evaluation of the specific trustworthiness of VO partners.

(c) **Interactions related to accessing services provided by ICT Infrastructure**

In order to effectively provide the required services, the TrustMan system invokes some basic services that are provided by the ICT Infrastructure (ICT-I), namely: the service for *data access* and the service for *security management* [Rabelo, et al., 2006].

- The service for data access supports the TrustMan system to manage performance data in its database, such as the related interactions with MSMS and PDMS for data acquisition.
- The service for security management supports the TrustMan system in the authentication of user services and in particular, the remote user services. It involves authenticating the source networks, corresponding security certificates, and so on that are necessary to maintain the required security.

(d) **Interactions related to accessing the TrustMan system by human users**

Interactions between human users and the TrustMan system are facilitated and achieved through the web interface. A web interface is designed to facilitate the interactions needed by human users based on the access rights as illustrated in Figure 6.3.

6.5.2 **The four-layer componential architecture of the TrustMan system**

Four-layer componential architecture of the TrustMan system adopts the standard definitions for web service technology. Thus it addresses the classification of internal components (system modules) into four layers. The components of TrustMan system, as shown in Figure 6.5, are classified into these four main layers, namely: the *presentation layer*, the *process layer*, the *description layer*, and the *message layer*, as described below.

(a) **Layer 1: Presentation layer**

This layer deals with the delivery of information from the process layer to the web interface in a format that is readable by humans. The layer also handles the transformation of data submitted by human users to the format that is acceptable by various modules at the process layer addressed below [Field & Hoffner, 2003].

The TrustMan system manages and deals with some sensitive information that in most cases the VBE member organizations may consider as proprietary, such as strategic business data. The designed web interfaces that facilitate the accessibility of information, as well as the execution of various supported services, are classified based on the user rights as addressed in "service S3" in Table 6.2, namely: the *public interface*, the *restricted interface* and the *protected interface*. Comparing against the components as classified in the interoperability architecture as shown in Figure 6.4, the following holds:

- The modules for the public interface belong to the group of “results provision” components in the interoperability architecture.
- The modules for the restricted and protected interfaces constitute components that belong to both the “user control components” (associated with user rights and roles), as well as the “services choreography” components (associated with classifying records of trust level of an organization) in the interoperability architecture.
**Chapter 6: Development of trust management system for VBEs**

(b) **Layer 2: Process layer**

The process layer is responsible for defining the logic of the invocation of various processes (modules) that need to be executed concurrently in order to provide the requested service. The process scheduling constitutes *orchestration and choreography* processes.

*Orchestration* refers to the logic (the sequence and flow) of the execution of various functions within one system process [Papazoglou & Georgakopoulos, 2003]. For example, in java programming this refers to the logic of the execution of functions within one object. Figure 6.6 illustrates a number of orchestrations within different single services, such as the order of execution of various actions/functions within (inside) the “*trustworthiness computation service*”.

*Choreography* represents the logic that will be followed in order to execute various modules, including invoking other services in order to provide an integrated service [Peltz, 2003]. As a means to exemplify this, the choreography of an integrated service for evaluating the specific trustworthiness of an organization is shown in Figure 6.6.

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**Figure 6.5: Four-layer componential architecture of the TrustMan system**

This figure shows at the high-level the internal components of the TrustMan system and their relations based on service oriented architecture (SOA) layer classification as addressed in this sub-section.

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**Legend**

- **Presentation layer (human user interfaces)**
  - Public
  - Restricted
  - Protected

- **Process layer (orchestration and choreography of processes with java)**
  - Base trust level assessment (For VBE member and applicant)
  - Specific trustworthiness evaluation (For VO partner and VBE roles)
  - VBE trust creation (For customers and invited organizations)
  - System management (For VBE administrator and trust expert)

- **Description layer (description for invocation and software interfacing with WSDL)**
  - TrustMan services described using web service description language (WSDL)

- **Message layer: For controlling invocation protocols and external communication**
  - SOAP extensions for security, reliability, correlation and transaction (The ECOLEAD ICT4)
  - SOAP
6.5 Designing the TrustMan system

![Diagram of TrustMan system](image)

Figure 6.6: The choreography of a service for evaluating specific trustworthiness

*This figure shows the order of invocations of a series of services, in order to accomplish the evaluation of specific trustworthiness of organizations as addressed below.*

This figure (Figure 6.6) shows the choreography of a set of services constituting the process of evaluating specific trustworthiness of an organization (as further explained below), and thus represents a part of the architecture of processes in TrustMan system. Consider the case of a user starting to evaluate the “specific trustworthiness” of a member organization in the VBE. The TrustMan system will first validate whether the user has the right to access the TrustMan system and the specific requested service. Once positively validated, the user will be granted the access. Then the service for selecting relevant trust criteria is invoked. Once the specific set of trust criteria is selected and submitted to the system, the service for computing trustworthiness will be invoked. The system then checks whether the organization whose specific trustworthiness needs to be evaluated is registered and its trust related data is available and complete in the system. When positive response is received from the services which check the registration and completeness of data, the data related to the organization will be retrieved and its specific trustworthiness will be evaluated. Lastly, the evaluation result is sent to the user. If at any stage a failure occurs then the process is terminated and the user receives a negative response with notifications about hints to the error, for example, the system may state that the organization is not registered in the VBE (Figure 6.6).

As shown in Figure 6.5 the components of TrustMan system at its process layer are classified into four groups, each providing one or more services, as addressed in Table 6.1, namely: (1) Components for base trust level assessments, which comprise service S1, (2) Components for specific trustworthiness evaluation, which comprise service S2, and S7, (3) Components for
trust creation, which comprise services S3 and S4, and (4) Components for system management, which comprise services S5 and S6. Process layer is the only layer which constitutes the services that are scheduled and executed to respond to the requests sent by users. Therefore, all components in this layer belong to “service choreography” components in the interoperability architecture as shown in Figure 6.4.

(c) Layer 3: Description layer
Description layer deals with the provision of the grammatical specifications of the services provided by the TrustMan system, to support the external invocations by remote systems. The description of a service applies “web service description language” (WSDL) to detail the following four fundamental parts:

- **Public interface:** Describes the public operations that are visible to external parties and thus can be invoked.
- **Data type information:** For all messages related to requests and responses, it describes the variables that need to be passed in order to access a specific service.
- **Binding information:** Related to the transport protocol, it defines the protocols necessary to access the service and facilitates external communication.
- **Address information:** For locating the specified service, it describes the server location and how it can be discovered in the UDDI.

This layer represents similar aspects to the service description part in the interoperability architecture, as shown in Figure 6.4.

(d) Layer 4: Message layer
The message layer defines the protocols for communication among systems and exchanging information across the network so that a receiving server/client may be able to interpret it [Peltz, 2003]. The standard applied communication protocol for web services is SOAP (Simple Object Access Protocol). Besides the standard SOAP protocol, additional mechanisms can be added to improve the security, reliability, adaptability, and so forth, of the system. At present, the ECOLEAD ICT-1 mentioned in Figure 6.5 that is developed by the ECOLEAD project provides a set of necessary features (such as security control, network certificates authentication, etc.) that smoothen the interactions between different ECOLEAD systems (including VMS that has TrustMan as a subsystem) that support collaborations among organizations [Rabel, et al., 2006].

6.5.3 Design of user interfaces of the TrustMan system
This section addresses the design of two interfaces for the TrustMan system to support the two types of users, namely: human users and system users.

(i) **Interface for human users:** Access to the TrustMan system by human users is achieved through a web interface developed as prototype and is controlled by three main parameters: user-name, password, and user-role. The user name refers to the user’s unique identification in the system. The password is created by the respective user during the first login. In addition to authorizing the user, these parameters serve to identify which type of information and/or services may be accessed with the current login details and the specific roles of the user. Thus the same user can access various parts of the system with a single sign on.

(ii) **Interface for remote-system users:** TrustMan system provides services that can be called by other systems by means of invocation based on the SOAP (simple object access protocol [Rhody, 2002]). Figure 6.7 presents the service invocation and interactions needed for an organization to update its trust related data at TrustMan system with information at its local repositories. The TrustMan system applies a certain level of
security across the network, such as the authentication of source network, as also provided by the ECOLEAD ICT infrastructure [Rabelo, et al., 2006]. The invocation request is expected to receive a local authentication certificate, as shown in step 1 in Figure 6.7, and if access to the requested service is granted by the TrustMan system control then a positive response is sent. If it is not granted then a negative response is sent. The interface supporting remote invocations of the TrustMan services is through WSDL interface at the description layer [Kreger, 2003].

![Diagram showing the process of external invocation for TrustMan system](image)

**Figure 6.7: External invocation for TrustMan system**

This figure shows the steps controlled by the TrustMan system for updating trust related data from a remote user site.

**6.5.4 Design of database schema for the TrustMan system**

In Chapter 4 we presented a record-based model of trust relationships between organizations. This model is used here to support designing a database schema for the TrustMan system as shown in Figure 6.8. We categorize the data applied in the analysis of inter-organizational trust into three groups, namely, organizational trust related data, data related to trust elements, and the basic data about the organization.

- **Organizational trust related data:** This information constitutes the values of trust criteria for each organization. This information indicates primarily the organization’s performance data expressed in terms of trust criteria and is used as the main input data for the services that assess the level of trust in an organization. Figure 6.8 shows an object-oriented model representing the database schema for the organizational trust related data.

- **Data related to trust elements:** This information constitutes a list and descriptions of trust elements, namely of the trust perspectives, trust requirements and trust criteria.

- **Basic data about organization:** This refers to the information that is necessary to accurately describe each physical organization or virtual organization. For physical organizations, this information may constitute the name, legal registration details, address, and so on. For virtual organizations, this information may constitute the VO coordinator details, launching and dissolving dates, involved partners, the customers, and so on.
Figure 6.8: Object-oriented schema for TrustMan system database

This figure shows a schema applied for the development of the relational database for the TrustMan system, to support the storage and management of organizational trust related data. The following short forms are applied to the Figure 6.8:

- **PK:** Primary key
- **HS:** Hardware standard
- **VO-ID:** VO-identification
- **FP:** Foreign key
- **OS:** Operating system
- **PS:** Protocol standard
- **OrgID:** Organization identification

6.6 Implementation and operation of the TrustMan system

According to [Ozcan et al., 2006], a well developed system is supposed to be: (a) generic enough to be *replicated* in different targeted environments, (b) *adaptable* enough to meet the
general (common) user requirements in each specific targeted environment, and (c) customizable enough to meet the needs of each specific user in the environment. These three indicators, namely, replicability, adaptability and customizability are discussed below in relation to the development of the TrustMan system.

(a) Replicability of the TrustMan system to different VBEs
Replicability refers to the ability of a system to support its own duplication for the purpose of deploying it in new environments without changing the characteristics or supported processes. Replicability of a system is analyzed considering its “core part” (sometimes known as the kernel or the central engine) that does not change when it is deployed in different environments. The TrustMan system is replicable considering the following aspects:

- **General set of trust criteria**: The mechanisms for assessing the trust level of organizations form the core part of the TrustMan system. These mechanisms are developed considering all trust criteria for organizations involved in the VBE so far identified as indicated in Figure 3.6 in Section 3.3. Thus any VBE can install the TrustMan system to meet its requirements related to management of inter-organizational trust.

- **Developed mechanisms for assessing trust level of organizations**: The mechanisms for assessing the level of trust in organizations rely on mathematical equations. The equations are formulated based on causal influence analysis between trust criteria, generic known factors and generic intermediated factors. Thus the mechanisms for assessing trust level of organizations implemented in the TrustMan system are also generic. Therefore, the TrustMan system can be replicated and deployed to different VBEs without the need to re-formulate the equations or re-develop the mechanisms for assessing trust level of organizations.

In relation to Adaptation and customization, the TrustMan system allows meeting the requirements of specific VBEs through its mechanisms for disabling or enabling features within the system. In this way the TrustMan system assures adaptability and customizability.

(b) Adaptability of the TrustMan system to different VBEs
In our approach, a series of trust criteria is applied for assessing the level of trust in an organization. Each VBE may, however, apply a different “pool of trust criteria”, which constitute the trust criteria that are selected by the VBE administrator from the generic set of trust criteria for all VBEs, during the establishment of the VBE. This selection of trust criteria depends on the preferences and perceptions of trust of the VBE administrator and the specific requirements of the VBE in relation to the management of inter-organizational trust. Furthermore, these preferences and perceptions might also be subject to the day-to-day changes that happen over time. In order to handle such situations, the TrustMan system must not only be replicable but also easily adaptable. We have addressed these aspects in the TrustMan system by implementing modules 9 and 10 (Figure 6.9) as addressed below.

(c) Customizability of the TrustMan system to different VBEs
A number of features need to be customized in order to ensure that the TrustMan system meets the requirements of each specific VBE. In practice, the customization of a system involves the reconfiguration of its user interfaces, user rights, external interoperability points, and so on. These aspects are generic to every system and therefore also considered in the customization of the TrustMan system. However, a unique feature of the TrustMan system, which is addressed below, is the customizability of the mechanisms for assessing the level of trust in organizations to meet the requirements of each user.
The mechanisms implemented in the TrustMan system for assessing the level of trust in organizations are designed on the basis of mathematical equations. As presented in Section 6.3.1, each mathematical equation constitutes a number of trust criteria and known factors. Each trust criterion and known factor is further related to others (trust criteria and known factors), as part of an operand in the equations, by means of a specified weight that indicates the preferences of the environment. The values of these weights (between 0 and 1, and their sum equals 1) might need to be further refined in order to meet the specific preferences of every trustor. The TrustMan system supports the customization of such weights in the implemented equations for two main purposes, namely: for supporting the assessment of base trust level of organizations and for supporting the evaluation of specific trustworthiness of potential VO partners. We have addressed these aspects in the TrustMan system by implementing module 11 (Figure 6.9) as addressed below.

The remaining of this section describes modules, functionalities, mechanisms and user interfaces developed for TrustMan system. In addition, it presents the trials aimed at examining the applicability of the TrustMan system performed through take-ups at different running industrial VBE networks.

6.6.1 Implementation of the TrustMan system

Services provided by the TrustMan system are developed in the Java language. A number of components (classes) are implemented and classified into modules. Each module constitutes a number of components (classes) that when executed provide a complete functionality e.g. each service as presented in Table 6.2. Figure 6.9 shows the modules (modules 1 to 11) constituting the TrustMan system, whose functions are further presented in this section. The description of each module is provided below:

![Figure 6.9: A global view of the modules in the TrustMan system](image-url)

This figure shows groups of implemented components of the TrustMan system, categorized into modules and the relations among those modules. The functionalities supported by each module included in this figure are described below, specified by its corresponding numbers in the figure.
1. **Module for trust level assessment:** It consists of a number of classes which provide basic algorithms for assessing an organization’s level of trust. The classes implement generic algorithms for computing various measures of levels of trust in organizations. For example, the mechanisms for computing the scores for intermediate factors, based on mathematical equations as presented in Chapter 5, are implemented in this module.

2. **Module for static assessment of trust level:** The classes in this module extend the classes in module 1; reusing the implemented generic algorithms. These classes provide algorithms for assessing the level of trust in organizations on the basis of a static (fixed or pre-defined) set of trust criteria such as a set of base trust criteria.

3. **Module for base trust level assessment:** The assessment of base trust level applies the set of base trust criteria selected by the VBE administrator during the establishment of the VBE. In addition to reusing mechanisms implemented in module 2, this module consists of mechanisms for rating various computed scores, such as the score per trust perspective as described in Chapter 5. This module also supports the generalization of level of trust in an organization into one category, as defined in the Trust-Meter which is shown in Figure 5.1.

4. **Module for dynamic assessment of trust level:** The classes in this module extend the classes included in the module for trust level assessment (module 1). This module provides additional mechanisms that are applied to assess an organization’s level of trust on the basis of a dynamic set of trust criteria, e.g. set of trust criteria for evaluating specific trustworthiness of VO partners (Chapter 5). In this case, the trust criteria to be applied for the assessment are selected by the user, and automatically applied in the assessment of level of trust of an organization.

5. **Module for selection of trust elements:** This module constitutes classes that provide algorithms for selecting trust criteria to support the evaluation of specific trustworthiness of an organization. As such, its operations are inherited by the classes in the modules for selecting perspectives (5a) and in modules for selecting criteria (5b).

6. **Module for trustworthiness evaluation:** This module supports the assessment of specific trustworthiness of organizations applying a set of trust criteria selected by the trustor to meet the requirements of a specific VO. Since the selection of trust criteria is dynamically performed, this module reuses mechanisms implemented in the module for dynamic assessment of trust level (module 4) for computing trust level of organizations. The classes in this module also extend the classes in the module for selecting trust elements (module 5) for the purpose of reusing the implemented mechanisms to dynamically acquire the preferred set of trust criteria. Figure 6.10 shows a web interface implemented in the TrustMan system that supports the selection of trust criteria.

7. **Module for the assessment of specialized base trust level:** The classes in this module support the assessment of base trust level of organizations that are invited to join a VBE for a specific role. The role of such invited organizations may for example be to fill certain gaps within the VBE, such as to provide missing competencies in the VBE. Thus, each invited organization will need its base trust level to be assessed vis-à-vis its business specializations and competencies. The classes in this module extend the classes in the module for dynamic assessment to reuse the algorithms for selecting trust perspectives. When the trust perspective is selected, all preferred trust criteria in that perspective are applied to the assessment of trust level of the invited organization. Therefore, the classes in this module also extend the classes in the module for static assessment of trust level (module 2) to reuse the implemented mechanisms for assessing base trust level when the perspective is known.
Figure 6.10: Web interface for selection of trust criteria to evaluate specific trustworthiness

This figure shows a screenshot of the user interface supporting the trustor with selecting specific set of trust criteria, related to evaluation of the trustworthiness of potential VO partners.

8. **Module for evolution support mechanisms**: This module is composed of classes that support the adaptability and customizability of the TrustMan in different VBEs.

9. **Module for adapting trust criteria**: The adaptation of the TrustMan system is enhanced by facilitating the possibility to change the applied set of trust criteria, without modifying any implemented mechanism. Although the entire set of general trust criteria is supported in the system, only the selected trust criteria for the VBE’s pool are applied in the assessment of organization’s level of trust in each VBE. “Logical operations” are implemented in the module as a way to support the changes of the set of preferred trust criteria for each VBE. Figure 6.11 shows an interface of the TrustMan system indicating four trust perspectives whose trust criteria were preferred and selected by IECOS VBE network during the take-up (see Table 6.3).
10. **Modules for tuning the set of trust criteria:** The set of trust criteria applied in the TrustMan system may need to be tuned due to changes of certain conditions within the VBE environment which may lead to the need for adding new emerging trust criteria such as the emergence of a completely new trust objective. The TrustMan system provides guidelines based on HICI approach (as presented in Chapter 3) to support identifying sets of new trust criteria, which can then be used to further tune the system. Figure 6.12 shows an interface for accessing the guidelines based on HICI approach for tuning trust criteria.

11. **Module for setting weights in equations:** Customization of weights in mechanisms for assessing the base trust level of organizations is done based on the preferences of the VBE administrator. The weights here are assumed to be valid for a relatively long period. They will not change until the VBE undergoes an evolution. The evolution can for example be extending the VBE with introduction of a new market focus, which in turn will require selecting new set of base trust criteria. The customization of weights in mechanisms used to evaluate the specific trustworthiness of potential VO partners is done based on the preferences of the VO planner. The weights assigned to trust criteria and known factors are assumed to be short-term and only valid for each individual VO. This configuration of weights is supported by this model shown in Figure 6.9.
Figure 6.12: Information about HICI approach in the TrustMan system
This figure shows a screenshot of the user interface with links (stage I to III) to the information on the HICI approach addressed in Section 3.2.

Another important aspect supported by the TrustMan system is the customization of the user interfaces. Users can set their preferences, for example, related to how the system should display results of the assessment of trust level. The interface may be for example to display detailed results including score of each intermediate factor (as shown in Figure 6.13). Alternatively, the final results of the trust level of organizations (see Figure 6.15).

The last aspect supported by the TrustMan system in relation to customization is setting up the ranges of scores for trust level and their interpretation. This is of particular importance for the evaluation of specific trustworthiness of organizations because the sensitivity of processes that VO partners may participate differs among brokered opportunities. Consequently, VO brokers may set a different range of scores for the same level of trust in organizations as shown in Table 5.1. Therefore, the TrustMan system supports user to define these ranges and their interpretation while evaluating the trustworthiness of organizations.
6.6 Implementation and operation of the TrustMan system

Figure 6.13: Detailed presentation of the trust level of an organization

This figure shows a screenshot of the user interface displaying detailed analysis results for an organization from the service for assessing the base trust level.

6.6.2 Take-ups of the TrustMan at running industrial VBE networks

The applicability and relevance of the TrustMan system was tested by four running industrial VBE networks, namely: IECOS (Mexico), CebeNetwork (Germany), SMT (Switzerland) and ISOIN (Spain) (see their description in Annex C). The testing of the TrustMan system followed three steps: (A) Setting up the VBE pool of trust criteria and deploying the TrustMan system, (B) Managing inter-organizational trust using the TrustMan system, and (C) Analyzing the improvements on the performed processes and the gained benefits.

A. Setting up the VBE pool of trust criteria and deploying the TrustMan system

In addition to reconfiguring the user interfaces, user rights, external interoperability points, and so on, the VBE administrators did set-up their specific VBE pool of trust criteria in the TrustMan system. The trust criteria included in their VBE pool were selected from the general set of trust criteria as presented in Section 3.3 based on the preferences and perceptions of trust for each VBE. Table 6.3 shows the VBE pool of trust criteria preferred by each VBE network.
Table 6.3: Different pools of trust criteria preferred by VBE networks
A: IECOS, B: CBN, C: ISOIN, D: SMT and B&C: joint VBE networks of ISOIN and CBN

<table>
<thead>
<tr>
<th>Trust perspective</th>
<th>Trust requirements</th>
<th>Trust criteria</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<th>B&amp; C</th>
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<td>Service contribution</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Standards complied</td>
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</tr>
<tr>
<td>Economical</td>
<td>Capital</td>
<td>Cash x x x x</td>
<td></td>
<td></td>
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<td></td>
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<td>Physical x x x x</td>
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<td></td>
<td></td>
<td>Material x x x x</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Cash in</td>
<td>x x x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Cash out</td>
<td>x x x x x</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Profit/Loss</td>
<td>x x x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operational costs</td>
<td>x x x x x</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>VO financial stability</td>
<td>Cash in</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Cash out x x x</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Profit/Loss x x x</td>
<td></td>
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<tr>
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<td>Financial standards</td>
<td>Auditing standards</td>
<td>x x x</td>
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<tr>
<td></td>
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<td>Auditing frequency</td>
<td>x x x</td>
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<td>Technological</td>
<td>ICT-Infrastructure</td>
<td>Network speed – Broadband x x x x</td>
<td></td>
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</tr>
<tr>
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<td></td>
<td>Interoperability x x x x</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Availability x x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technology standards</td>
<td>Protocol supported</td>
<td>x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>Software standards x x x</td>
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<td></td>
<td></td>
<td>Hardware standards x x x</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Security standards x x x</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Platforms</td>
<td>Operating systems x x x</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Programming languages x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Platform experience</td>
<td>Applied in VO x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>External project applied x x x</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>Duration held x x x</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Managerial</td>
<td>Stable management</td>
<td>Years in power x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Legal status (management) x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frequency of power change x x x</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>VO-Collaborative behaviour</td>
<td>VO opportunistic behaviour x x x x</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>VO collaborations x x x x</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VO leadership history x x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reliability</td>
<td>Quality x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adherence to delivery dates x x x x</td>
<td></td>
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</tr>
</tbody>
</table>
B. Managing inter-organizational trust using the TrustMan system

During the experimentation, a number of processes related to the management of trust between organizations were performed by the VBE networks using services provided by the TrustMan system. We have categorized these processes into five groups (P1 to P5), particularly related to the following:

P1: Improving the understanding of trust concepts: Organizations need to properly understand the concepts of trust as perceived within the VBE in order to accept the results of the assessment of their trust level. To support this process the TrustMan system maintains information related to the following among others: (1) All trust elements applied to the assessment of trust level of organizations, (2) Presentation and interpretation of trust level of organizations, and (3) Mechanisms for assessing trust level. These pieces of information can be accessed by all VBE member organizations. Figure 6.14 represents a screenshot of the TrustMan system showing (at higher-level of aggregation) the description of the mechanisms used to assess the level of trust in organizations. This process is supported by services 3, 4 and 6 as presented in Table 6.2.

![Figure 6.14: Description of mechanisms for assessing trust level of organizations](image)

This figure shows a screenshot of the user interface displaying information about the mechanism for assessing the trust level of organizations as presented in Section 6.3.1, indicating how it is formulated in the TrustMan system to enhance the understanding of users.
P2: Presenting and interpreting the trust level of organizations: Upon assessing the trust level, the trustor organization shall present the results to all trustee organizations and explain the validity and correctness of their levels of trust. Thus, the trustor needs to be prepared to describe the ranges of scores for the trust level and their related interpretation as exemplified in Table 5.1.

P3: Selection of trust criteria: The services provided by the TrustMan system to support this process are aimed at facilitating a VO broker to select the trust criteria that meet the requirements of the brokered opportunity. This process is supported by service 2 as presented in Table 6.2 and its user interface is shown in Figure 6.10.

P4: Assessment of trust level of organizations: This process comprises two activities, namely, assessing the base trust level of organizations (performed by the VBE administrator) and evaluating specific trustworthiness (performed by the VO broker). This process is supported by services 1 and 2 as presented in Table 6.2. The VBE administrator uses the service for assessing trust level of organizations for two purposes: (1) To get a general picture of the balance of levels of trust in organizations in the VBE (see Figure 6.15), and (2) To get detailed results of the analysis of the trust level of one organization (see Figure 6.13).

Figure 6.15 shows results of the process of assessing the base trust level of all member organizations in the VBE. The figure also indicates those organizations whose trust related data is not fully submitted in the system.

Figure 6.15: Results of assessment of trust level for all organizations in the VBE

This figure shows a screenshot of the user interface displaying the final results of the assessment of trust level for all organizations in the VBE. The interface also indicates those organizations for which some trust related data is not complete in the system.
P5: Management of trust related data: This process is performed by each organization in the VBE to ensure that its trust related data is up-to-date. Every organization can access the TrustMan system to use the service for managing trust related data (service 4 as presented in Table 6.2) to view its own data and submit new data as shown in Figure 6.16.

Figure 6.16: Viewing and submitting organizational trust related data
This figure shows a screenshot of the user interface displaying a form for submitting trust related data related to the structural perspective. The interface also shows the previous data existing in the TrustMan system related to the logged in organization.

C. Analyzing the improvements on performed processes and gained benefits
Business organizations aim to optimize their profit while operating in a market. An organization’s profit can be enhanced by addressing among others, the following issues:
- Raising the price of products
- Acquiring more customers and increasing sales
- Minimizing production/delivery resources
- Reducing the time of production or delivery of products/services.

Our research provides conceptual results (methodologies, approaches, mechanisms, etc.) as presented in Chapters 2, 3, 4, and 5 and software prototypical result (the TrustMan system) presented in this chapter. The resulting software has the potential of helping organizations enhance their collaborative performance and in doing so raise their profits. When organizations trust each other they can efficiently collaborate and this consequently enhances the performance of both organizations and the network. However, our research results are unlikely to directly influence the price of their products, nor are these results likely to directly enhance the acquisition of more customers.
Our research results may, however, influence the use of resources and the time needed to accomplish certain processes. For example, the services supporting processes related to the assessment of level of trust in VO partners will reduce the number of human resources and the time needed to perform such processes. This will result in less VO setup cost, which will enhance the profit achieved. Thus, while testing the TrustMan system, the VBE administrators evaluated improvements on processes that were performed using the TrustMan system.

To indicate the quality of services provided by the TrustMan system in terms of improvements on performed processes two groups of indicators were used: quantitative indicators and qualitative indicators.

1. **Quantitative indicators**: These are indicators that can be measured in numbers and are applied to quantitatively analyze and evaluate the improvements on the processes supported by the TrustMan system. Table 6.4 describes two quantitative indicators, namely: *resources and time*, applied to evaluate the TrustMan system.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Resources</td>
<td>Increase or decrease in percentage</td>
<td>Resources refer to the commodities and personnel that are used in the production of goods and services. Resources may include natural resources (commodities that are valuable in their relatively natural form, such as machines, and so on), human resources, financial resources, etc. Considering our software result the possible improvements in performing the above mentioned processes (P1-P5) can be observed in terms of the reduction of the number of involved human resources. This indicator is measured as a ‘percentage’ of change of the number of people involved in a certain process.</td>
</tr>
<tr>
<td>C2: Time</td>
<td>Increase or decrease in percentage</td>
<td>Time here refers to the days, weeks, months, and so forth that have elapsed between the starting point and the finishing point of a certain process. It is measured as a ‘percentage’ of change of the time needed to accomplish each process.</td>
</tr>
</tbody>
</table>

The quantitative evaluation of the TrustMan system was done by VBE administrators by estimating the reduction of time and resources for the five processes (P1-P5) as introduced earlier in this section. Table 6.5 shows the estimated reduction of time and resources (in terms of percentages) for the five processes. The results were collected using a questionnaire presented in Annex C. As shown in Table 6.5 there was reduction of time and human resources for all process performed by the VBE networks using the TrustMan system. The graphical representation (Figure 7.2) and the interpretation of these results are presented in Chapter 7.
Table 6.5: Results of evaluation of the TrustMan system using quantitative indicators
(The numbers in this table refers to percentage of reduction of time and resources)

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISOIN</td>
<td>Time</td>
<td>50</td>
<td>20</td>
<td>45</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Resource</td>
<td>20</td>
<td>25</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>IECOS</td>
<td>Time</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Resource</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>CBN</td>
<td>Time</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Resource</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>SMT</td>
<td>Time</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Resource</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Average</td>
<td>Time</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Resource</td>
<td>15</td>
<td>16</td>
<td>15</td>
<td>18</td>
<td>15</td>
</tr>
</tbody>
</table>

2. **Qualitative indicators**: These are indicators that cannot be measured with numbers and are applied to evaluate the TrustMan system using some grading scheme. Table 6.6 shows five qualitative indicators applied to evaluate the TrustMan system. It also provides a brief justification for choosing and applying each indicator in the evaluation.

Table 6.6: Qualitative indicators applied to evaluate the TrustMan system

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3: Innovation</td>
<td>SoA, innovative or very innovative</td>
<td>State of the art and practice (SoA) refers to innovation as the development of concepts and tools that do not already exist in the market. Using this indicator, VBE administrators can indicate the quality of services provided by the TrustMan system as compared to those services that they have been applying in their activities.</td>
</tr>
<tr>
<td>C4: Reliability</td>
<td>High, normal, or low</td>
<td>Reliability is the ability of a system to perform and maintain its functions in routine circumstances, as well as in hostile or unexpected circumstances. To be reliable, a system must perform its functions and produce results of consistent quality, irrespective of the time or running environment. Using this indicator, VBE administrator can indicate the quality of services provided by the TrustMan system when remotely accessed using computer networks. This aspect is important considering the distributed nature of VBEs.</td>
</tr>
<tr>
<td>C5: Usability</td>
<td>Easy, normal, or difficult</td>
<td>Usability refers to the effectiveness, efficiency, and satisfaction that users can achieve when using a particular system. High usability means that a system is: easy to learn and remember, efficient, visually pleasing and fun to use, quick to recover from errors, etc. Users of the TrustMan system are decision makers of organizations who aim at getting information about the trust of other organizations for the purpose of making strategic decisions, such as establishing business collaborations with them. These users might not have strong expertise in computer science and mathematics and thus the TrustMan system must have user friendly interfaces.</td>
</tr>
<tr>
<td>C6: Expectation</td>
<td>Highly achieved, achieved, not achieved</td>
<td>We assumed that the demonstrating networks have certain objectives that they were expecting to achieve by adapting the developed solutions. The networks are able to indicate how their expectations were achieved.</td>
</tr>
<tr>
<td>NA - Not Applicable</td>
<td>NA (Not Applicable)</td>
<td>The task is completely new and has not previously been performed in the network. Therefore, NA refers to the fact that the comparative and quantitative evaluation is not possible due to lack of this feature in the past.</td>
</tr>
</tbody>
</table>

The evaluation results collected during the take-up were analyzed and summarized on the basis of the four qualitative indicators (C3 – C6) as shown in Table 6.7. The results were collected using a questionnaire presented in Annex C. The graphical representation (Figure 7.1) and the interpretation of these results are presented in Chapter 7.
To quantitatively analyze the collected evaluation results that applied qualitative indicators, these grading schemes were mapped into some range of numbers (scores). The mapping was as follows:

- Highest grade (i.e. very innovative, high, easy, highly achieved) is mapped into a score of 3,
- Medium grade (i.e. innovative, normal, and achieved) is mapped into a score of 2, and
- Lowest grade (i.e. SoA, low, difficult, and not achieved) is mapped into a score of 1.

After conversion, a numerical analysis was performed focusing on the average score for all processes performed by each VBE for every evaluation indicator. For example, the results from ISOIN network are converted as follows:

1. An average score for each indicator was calculated based on all processes: innovation is 2.8, reliability is 3, usability is 2.6, and expectation is 2.6.
2. The average score for all indicators was computed for ISOIN: 2.75.

The average score represents the general acceptance of our results by the specific VBE networks as shown in Table 6.7 and graphically represented in Figure 7.1.

Table 6.7: Results of evaluation of the TrustMan system with qualitative indicators

<table>
<thead>
<tr>
<th>VBEs</th>
<th>Processes</th>
<th>Qualitative evaluation indicators</th>
<th>Average score (0-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Innovation</td>
<td>Reliability</td>
</tr>
<tr>
<td>ISOIN</td>
<td>P1</td>
<td>Very innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P2</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P3</td>
<td>Very innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P4</td>
<td>Very innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P5</td>
<td>Very innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IECOS</td>
<td>P1</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P2</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P3</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P4</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P5</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBN</td>
<td>P1</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P2</td>
<td>Very innovative</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>P3</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P4</td>
<td>Very innovative</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>P5</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMT</td>
<td>P1</td>
<td>Very innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P2</td>
<td>Innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P3</td>
<td>Very innovative</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>P4</td>
<td>Very innovative</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>P5</td>
<td>Innovative</td>
<td>High</td>
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</tbody>
</table>
6.7 Chapter discussion and conclusion

This Chapter addresses the analysis, design and implementation of functionalities and services to support the management of inter-organizational trust in VBEs. It presents the development of the TrustMan system and services that address the requirements for inter-organizational trust in VBEs. These requirements have been identified through the requirement analysis of the TrustMan system (mainly addressed in Chapters 1 and 6), involving trust experts and VBE experts and through performing some empirical studies at running industrial VBEs.

The chapter first presents the concepts of the VBE management system (VMS), and then the VMS’s subsystems and the interactions among those subsystems. The chapter then presents in detail the development of the TrustMan system and focuses specifically on each of the following aspects:

+ **Specification of the TrustMan system**: As a step towards developing the TrustMan system, we have performed the analysis to identify its users and their user requirements, and based on the user requirements we have specified the needed functionalities and services.

+ **Architectural design of the TrustMan system**: In this thesis we have adopted and applied the service oriented architecture and specifically the web service technology standards to design the architectures of the TrustMan system. Based on these concepts, two kinds of architectures (the interoperability architecture and four-layer componential architecture) are designed for supporting different aspects during the implementation of the TrustMan system. Furthermore, some partial architectures are also designed for the TrustMan system, such as those related to orchestration and choreography of services based on web service standards.

+ **Implementation aspects applied to the development of the TrustMan system**: The implementation of the TrustMan system is done in the Java language. Since Java is platform independent, the adaptability of the TrustMan system to different technical running environments is assured.

+ **Replicability, adaptability and customizability of the TrustMan system**: As addressed in Section 6.6.1, the TrustMan system is replicable because it: (1) uses general set of trust criteria, (2) uses generic mechanisms for assessing trust level of organizations, and (3) provides mechanisms for enabling or disabling its features which assures its adaptability and customizability. It is also adaptable because it supports: (i) setting-up a pool of trust criteria to meet the requirements of every specific VBE, and (ii) tuning a set of trust criteria when the system when some conditions have changed in the VBE such as emergence of new trust objectives. Furthermore, it is also customizable because it supports: (a) tailoring the mechanisms for assessing the level of trust in organizations to meet the requirements of each specific user by changing the weight for each trust criteria in the implemented equations, and (b) configuring user interfaces to meet requirements of a specific user in the VBE.

+ **Take-ups and experimentation of the TrustMan system**: The TrustMan system has been tested by four running industrial VBE networks, and the evaluation results are collected, in particular those related to indicators presented in Table 6.4 and Table 6.6. The evaluation of the TrustMan system is also discussed in Chapter 7.

In response to the MRQ4 and its related sub-question (SRQ4.1, SRQ4.2, and SRQ4.3), this chapter has addressed the development of services supporting the processes relating to the management of inter-organizational trust in VBEs. In Chapter 7 an integrated view is given on how all the research questions as presented in Section 1.5 are addressed.