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ACRONYMS 9
GLOSSARY 10
CHAPTER 1. INTRODUCTION AND RESEARCH PROBLEM ANALYSIS 11
1.1. Introduction 11
1.2. Virtual organisations Breeding Environments 17
1.2.1. VBE reference model 17
1.2.2. VBE management challenges 24
1.2.3. VBE-ontology and ColOnto system 30
1.3. Research motivation and problem area description 33
1.3.1. Research background 33
1.3.2. Research problem areas 34
1.4. Summary of research objectives and research questions for the thesis 37
1.5. Research and development methodology 39
1.6. ECOLEAD project 39
1.7. Thesis structure 43
1.8. Conclusions 43
CHAPTER 2. RELATED WORK AND REQUIREMENTS ANALYSIS 45
2.1. Introduction 45
2.2. Positioning among related state-of-the-art research 47
2.2.1. VBE-ontology engineering methodology 48
2.2.2. VBE conceptualisation and modelling 50
2.2.3. Relevant ontology maintenance and management functionalities 51
2.2.4. Relevant models and functionalities for organisational profiles and competencies 52
2.3. State of the art in practice of VBEs 57
2.3.1. Profile models 57
2.3.2. Competency models 58
2.3.3. Profile management 58
2.3.4. Competency management 58
2.4. Requirements analysis 59
2.4.1. Generic requirements 59
2.4.2. Fulfilling stakeholders’ requirements 61
2.5. Conclusion 64
CHAPTER 3. CONCEPTUAL DESIGN OF COLONTO SYSTEM 65
3.1. Introduction 65
3.2. VBE-ontology 66
3.2.1. Step 1 - Purpose and definition 67
3.2.2. Step 2 - Formality 69
3.2.3. Step 3 - Scope / Subject matter 69
3.2.4. Step 4 – Building 73
3.3. Profiles and competencies 81
3.3.1. Generic model of profile 82
3.3.2. Generic model of competency 86
3.3.3. Domain level for profile and competency models 92
3.3.4. Aggregate and collective profiles and competencies 92
3.4. Conclusion 94
CHAPTER 4. FUNCTIONAL DEVELOPMENT OF THE COLONTO SYSTEM 95
4.1. Introduction 95
## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>VO</td>
<td>Virtual Organisation</td>
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<tr>
<td>VBE</td>
<td>Virtual Organisations Breeding Environment</td>
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<tr>
<td>SME</td>
<td>Small or Medium Enterprise</td>
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<tr>
<td>ColOnto</td>
<td>Collaborative networks Ontology system</td>
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<tr>
<td>ODMS</td>
<td>Ontology Discovery and Management System</td>
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<tr>
<td>PCMS</td>
<td>Profile and Competency Management System</td>
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<td>ARCON</td>
<td>A Reference model for COllaborative Networks</td>
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<tr>
<td>ECOLEAD</td>
<td>EC-funded integrated research project “European Collaborative networked Organisations LEADership initiative”</td>
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<tr>
<td>GRQ</td>
<td>General Research Question</td>
</tr>
<tr>
<td>RQ</td>
<td>Research Question</td>
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### Glossary

<table>
<thead>
<tr>
<th><strong>Virtual Organisation (VO)</strong></th>
<th>Virtual Organisation is a goal-oriented collaborative network of partner organizations, configured to deliver joint products and services.</th>
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<tr>
<td><strong>Virtual Organisations Breeding Environment (VBE)</strong></td>
<td>Virtual organisations Breeding Environment is an association of organisations and a set of related supporting institutions which adhere to a base long-term cooperation agreement and adoption of common operating principles and infrastructures, with the main goal of increasing their preparedness for collaboration within potentially configured Virtual Organisations.</td>
</tr>
<tr>
<td><strong>VBE-ontology</strong></td>
<td>VBE-ontology provides a unified and formal specification of the heterogeneous concepts in the VBE environments, allowing these concepts to be easily accessed by and communicated between the human and the application systems, for the purposes of VBE knowledge modelling, collection, processing, analysis, and evolution.</td>
</tr>
<tr>
<td><strong>Concept-reusability level of the VBE-ontology</strong></td>
<td>Concept-reusability level partitions the VBE-ontology into two sets/levels of concepts to represent that they can be reused: (1) by all VBEs – core level, or (2) by all VBEs from the same domain / area of activity – domain level.</td>
</tr>
<tr>
<td><strong>Work area of the VBE-ontology</strong></td>
<td>Work area is a partition of the VBE-ontology that includes the set of concepts while can be reused within one specific process/functionality of the VBE management, i.e. related to specific VBE management service, functionality, tool, or task.</td>
</tr>
<tr>
<td><strong>Sub-ontology of the VBE-ontology</strong></td>
<td>Sub-ontology is a partition of the VBE-ontology representing on one hand an independent physical unit, i.e. that can be used independently by VBE’s human and software agents, but on the other hand its complementarity to other sub-ontologies, i.e. the fact that all sub-ontologies together comprise the complete VBE-ontology.</td>
</tr>
<tr>
<td><strong>Exemplar of the VBE-ontology</strong></td>
<td>An exemplar of the VBE-ontology is a partition of the entire VBE-ontology that represents: (1) the whole core level of the VBE-ontology, and (2) a subset of specialised domain levels from the specific domains, in which the VBE operates.</td>
</tr>
<tr>
<td><strong>VBE member organisation’s profile</strong></td>
<td>The VBE member organisation’s profile consists of specific set of identifying characteristics (e.g. name, address, capabilities, etc.) about each organisation, that are collected specifically to facilitate their semi-automated selection for involvement in some specific line of activities / operations in VOs.</td>
</tr>
<tr>
<td><strong>VBE member organisation’s competencies</strong></td>
<td>VBE member organisation’s competencies in VBEs represent up-to-date information about their capabilities, capacities, costs, as well as the conspicuities, illustrating their accuracy, all aimed at qualifying organisations for VBE participation, and mostly geared towards their VO involvement.</td>
</tr>
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Chapter 1

Introduction and research problem analysis

With the pre-establishment of long-term associations/alliances among small and medium-sized enterprises (SMEs), an environment can be formed, aiming to increase and facilitate potential SME partnerships, such as those in Virtual Organisations (VOs), in order to approach and take advantage of the emerging market & society opportunities. These environments can thus serve as the VO breeding environments. Our research is focused on the design and development of the 2nd generation Virtual organisations Breeding Environments (VBEs), and addresses many of the challenges related to the creation of VBEs and their effective operation. This Chapter discusses a set of problem areas and open questions targeted by our research, as well as the methodology used to tackle these problem areas. As such, it first defines the existing background of this area (the so-called 1st generation) VBEs, and specially introduces four high-level research challenges related to their creation and operation, including: (i) facilitating the common understanding of environmental concepts, (ii) effective assistance with the VBE instantiation in different sectors and domains, (iii) supporting the required dynamism and scalability of VBEs and (iv) boosting and balancing the involvement of VBE members in the VOs. It further focuses on the need for development and management of VBE ontologies as the basis for addressing the above-mentioned challenges, and presents a methodology for development and evolution of such a VBE ontology. At the end, the Chapter briefly presents the context of the EC-funded integrated research project ECOLEAD, within which this research is performed. This Chapter ends with a summary of the author’s publications, presentation of the structure of this thesis, and the conclusions.

1.1. Introduction

Stimulated by fast technology development, the fluctuating customer demands, and turbulent market and society conditions, small and medium-sized organisations/enterprises, the so-called SMEs, are especially threatened. Having limited resources (machinery, human, etc.) and restricted capacities and potential to get involved in innovation, SMEs have far less chances to respond to the complex emerging opportunities, and to compete with larger organisations.

As practice has shown however, SMEs’ chances of remaining competitive increase when they join forces and work together, e.g. within some new forms of organisations [1] called the Virtual Organisations (VOs) [2]. As members of a VO, organisations benefit from combining their resources, capacities and expertise, in order to create a larger/stronger entity in the market/society, when also agreeing to share their profits and losses. In the manufacturing sector for instance, SMEs establish VOs and together produce more complex and cost/quality effective products, which they cannot produce individually. Similarly in the service industry, SME service providers, e.g. hotels, airlines and car rental companies join efforts and form VOs, either to offer more integrated value-added packages, or to develop more personalised and tailored services for their end customers or travel agencies.

However, both research and practice in the area of VOs have shown [3] that pre-establishing some form of longer-term networks among the SMEs, the so-called Virtual organisations Breeding Environments (VBEs), can optimise and facilitate the effective / agile formation and setup of the VOs [4][5]. VBEs primarily aim to provide the set of
required functionalities that on one hand increase the discovery of suitable market opportunities and identify the best-fit partners to address the opportunity and support the VO formation and establishment, and on the other hand prepare their member organisations in advance, for more effective collaboration within the established VOs.

Figure 1.1 illustrates three different ways of addressing the emerging opportunities within the market/society. Also for each trajectory, its related differences and/or advantages are emphasised.

**Trajectory 1**
- Difficulties:
  - The organization may not have sufficient competencies and resources

**Virtual Organization (VO)**
- Coordinating partner organizations in performing their sub-tasks

**Trajectory 2**
- Difficulties:
  - The broker must spend too much time and effort to find other partner organizations, and to establish working and sharing principles among them, and to create the needed common collaboration environment and infrastructure

**Virtual organizations Breeding Environment (VBE)**
- A priori preparation of member organizations for effective collaboration
- Creation of the needed commonality
- Formation of VOs

**Trajectory 3**
- Advantages:
  - A broker inside the VBE selects organizations with complimentary competencies and resources covering the needs of the emerged opportunities
  - VBE forms the VOs fluently and dynamically

This Figure illustrates three different ways of addressing emerging opportunities within the market/society as three different Trajectories to follow by organisations/SMEs: Trajectory 1: by a single organisation, Trajectory 2: through formation of a VO configured from the open universe of organisations and Trajectory 3 by formation of a VO inside a VBE. This Figure also shows the main difficulties faced by SMEs in Trajectories 1 and 2, which are eliminated in Trajectory 3.

For the requirement analysis stage, as well as the validation of our research, we collaborated with a number of existing VBEs from Europe and Latin America (see annex A for the list of these networks), to which we refer in this thesis as the 1\textsuperscript{st} generation VBEs. Particularly, we have studied their current practices and challenges [6]. In this study, we have also performed an analysis of their needed requirements in order for them to evolve, and develop the 2\textsuperscript{nd} generation [7]. Our main observations and gathered requirements about modelling and management of the knowledge, information, and data in these VBEs are addressed below, followed by introducing our planned research approach for this thesis.

As the base, to support its fundamental functionalities and operations, every VBE needs to accumulate a wide variety of data, information and knowledge. Influenced by [8], we define the data, information and knowledge in VBEs as follows: VBE data represent some sets of symbols, which are typically held in the cells of the VBE database. As such, these data
have no significance beyond their existence and do not have meaning of their own. *VBE information* represents data that have been given meaning by way of expressing their inter-relational connections, e.g. within the relational database that we develop for VBEs, however this "meaning" may not be necessarily useful for the VBE stakeholders. The *VBE knowledge* on the other hand, represents an appropriate set of collected information and their related context within the VBE, intended to facilitate VBE functionality and its stakeholders. Knowledge accumulated in VBEs should be commonly understood by all its stakeholders, as well as properly formatted and stored in form of information and data, so that it can be effectively retrieved, processed, and analysed.

The data, information, and knowledge related to each VBE must be gathered from two sources: (1) from the generic VBE specification and the VBE reference model, representing what is shared by all VBE instantiations and (2) from the specific domains of activities for this VBE (e.g. metalworking, health-care, etc.). These two types of information/knowledge sources are illustrated in Figure 1.2. An initial brief description of these two sources and their different kinds of elements is also provided below.

### Figure 1.2 – Variety of data/information/knowledge accumulated at each VBE

This Figure illustrates two different types of data/information/knowledge that need to be accumulated in each VBE, including (1) generic data/information/knowledge about VBEs, represented by the generic reference models of the VBE (e.g. ARCON-based [9][10]), which consists of both elements of its endogenous and exogenous dimensions and (2) specific data/information/knowledge, related to the domain of activities considered for the VBE.

The *generic* VBE data, information and knowledge address the VBE aspects and characteristics common to all VBEs. Here, the main types are already specified by the ARCON reference model (as further outlined in detail in Section 1.2.1).

The data, information and knowledge about activity *domains* are related to the main processes, products, services, expertise and competencies that are available within a specific VBE domain of activity or business area.
Considering the complexity and heterogeneity of generic VBE structure, and the specificity of its domain applications, in collaboration with a number of running 1st generation VBEs, we have identified challenging requirements for supporting different stages of its life cycle (i.e. creation/foundation, operation, evolution, metamorphosis) as illustrated in Figure 1.3. The arisen questions must be answered to successfully support the establishment and operation of 2nd generation VBEs.

![Figure 1.3: Challenging questions in VBEs and their root causes](image)

This Figure illustrates a number of main challenging questions that both the management of 1st generation VBE and their member organizations face during different stages of the VBE life cycle. Most of these challenges are caused by the complexity and heterogeneity of VBE environments, specialisation of VBE application domain, as well as by the dynamic nature of the market and society where VBEs operate.

**Challenge I - Establishing common understanding of VBE aspects.** There is still a lack of common definition for the generic VBE concepts, which in turn causes the lack of understanding and effective communication of concepts within the VBEs [11]. In practice, this problem becomes even more severe due to both the need for merging and interrelation of different types of generic concepts within the VBE, and the continuous and dynamic joining of new members/actors to the VBE, each bringing their own new domain-dependent knowledge and terminology.

**Challenge II - VBE instantiation to different domains.** VBE instantiation to every specific domain of organizations activities is costly and time/effort consuming. This is because every VBE at its creation step should establish the common ICT infrastructure, the VBE working and sharing principles, as well as customization and parameterization of its ICT infrastructure which are not straightforward.

**Challenge III - Supporting dynamism and scalability of VBEs.** In order to capture as many as possible the emerged opportunities, VBEs need to be very dynamic in adapting to new trends. This means potentially inviting more members and increasing its size. The new members shall provide the VBE administrators with information about their competencies and
capacities, and similar to their members they should constantly provide updates of this information. Some intelligent ICT-supported approaches must be developed to facilitate these processes.

**Challenge IV - Balancing and boosting VO involvement.** The variety of representation as well as the dynamism in features and abilities of the VBE member organisations pose obstacles to their processing for the purpose of their involvement in potential VOs. At present, the lack of homogeneity in organisations’ representation in 1st generation VBEs has resulted the lack of fair chances of being involved in configured VOs.

![Figure 1.4 – The VBE management challenges](image)

This Figure illustrates four main challenges for VBE management system, which are addressed in this thesis. For each challenge, the VBE stakeholders that are affected by the challenge are specified. The Challenges I to III are related to the generic variety of VBE information, while the Challenge IV is related to the representation of VBE members’ profile and competency information.

To address the above information-handling-related challenges, this thesis suggests the development and management of an ontology for VBEs. Considering the traditional definition of ontology [12] as: “a specification of a representational vocabulary for a shared domain of discourse”, the use of ontology lies at the heart of developing the management system functionalities for the emerging VBEs (2nd generation VBEs). The VBE ontology can therefore serve as the shared conceptualisation for the VBE, which needs to be communicated among all involved people and application subsystems. Furthermore, it can provide a base for common understanding among the stakeholders at the VBEs, as well as for creating interoperability among different VBE management tools.

This thesis details at the development of the **VBE-ontology** - a generic and unified ontology for VBEs, which is built up to specifically address Challenges I, II and III mentioned above. Furthermore, a main part of this ontology focuses on the modelling and specification of the profiles and competencies of VBE member organisations. The latter is a vital source of information in the VBEs to support the match-making process for the VO configuration. This aspect of VBE-ontology addresses challenge IV mentioned above. As such, our proposed unified VBE-ontology, uniformly represents all VBE data, information, and knowledge, related to the above four challenges of VBE management system. These aspects are briefly defined below, while the more detailed description of the goals for the VBE-ontology is provided in Section 1.2.3.

The **VBE-ontology** developed in this thesis addresses Challenge I above through its representation of concepts and terms in a detailed and uniform format, so that it can be shared
and commonly understood by a variety of VBE stakeholders. It responds to Challenge II by serving as a data model useful for development of the VBE databases, for specification of a VBE data classification, and for parameterising VBE management tools. Furthermore, it responds to Challenge III through provision of semantics that support semi-automated management of VBE information, which in turn accelerates the information management processes of the VBEs. Finally, it responds to Challenge IV by providing means for formal and uniform representation of characteristic information related to VBE members, such as their profiles and competencies, which can in turn support the balanced involvement of organisations in potential VOs.

Furthermore, to comprehensively address challenges I to IV with ICT-based supporting tools, the thesis introduces the development of a system called the ColOnto (Collaborative networks Ontology system), which is built on top of the VBE-ontology. The ColOnto consists of two main parts: (1) the conceptual part, representing the VBE-ontology and (2) the functional part representing a set of functionalities supporting the maintenance and management of the VBE-ontology. A methodology for development of the ColOnto is outlined, in Section 1.5.

The main contributions of this thesis are twofold:

• Describing the methodology applied for design and engineering of a unified ontology for VBEs, called the VBE-ontology (addressed in Chapter 3). This ontology introduces a compound structure with different partitions for each specific VBE information management component. One main partition of this ontology represents and specifies the profiles and competencies of the VBE member organisations.
• Designing and development of an information management system and a set of specific functionalities to tackle the VBE-ontology (addressed in Chapter 4). This system, called the Ontology Discovery and Management System (ODMS) introduces among others a set of specific services to help both VBE members in familiarising themselves with the VBE concepts, and the VBE manager in parameterising different VBEs’ management sub-systems. One main component of the ODMS addresses the Profile and Competency Management System (PCMS), which in turn introduces the set of functionalities required for management of profiles and competencies of different VBE actors.

The other two chapters of this thesis cover other complementary aspects of the research: Chapter 2 specifies the background and base required for development of ColOnto, including the state of the art in research and practice, and a set of requirements which are collected from running 1st generation VBEs related to ColOnto, and Chapter 5 addresses the evaluation and validation of the ColOnto.

The rest of this Chapter is organised as follows: Sub-section 1.2 first provides a brief background description on the VBEs. It then narrows down to the problem area of this thesis and the need for VBE ontologies, as well as addressing the specific ontology for profile and competency management in VBEs. Sub-section 1.3 outlines the reasoning behind this research, namely it addresses the main challenges regarding the development and management of the VBE-ontology. Sub-section 1.4 introduces the specific research questions addressed in the thesis, as well as the main research objectives and scope. Sub-section 1.5 addresses the methodology applied to this research. Section 1.6 describes the ECOLEAD project, within which this research was primarily conducted, and provides a list of the author’s publications through which the research results are addressed. Sub-section 1.7 defines the structure of the thesis in more detail, and Sub-section 1.8 concludes this chapter.
1.2. Virtual organisations Breeding Environments

The need for Virtual Organisations - VOs, as new organisational forms which extend the capabilities and capacities of existing enterprises and makes them more competitive in the market and/or society, was first identified in the 1970s, mostly in the early works of economists such as [13]. Until the last decade however, research on Virtual Organisations as a goal-oriented network, configured to deliver joint products and services, have assumed that partners of VOs can be easily identified, and those most suitable can be simply selected from the wide open universe of organisations, e.g. nowadays through the Internet. But this assumption has overlooked a number of challenging obstacles to this process, among which the following can be mentioned [14]:

- How to find out about the mere existence of potential partners in the open universe and how to deal with incompatible sources of information?
- How to acquire basic characterising profile and competency information about organisations, when there is no common template or standard format?
- How to quickly establish the required inter-operable collaboration infrastructure for VOs, given the multi-levels heterogeneity of autonomous organisations, and the diversity of their interaction systems?
- How to build trust among organisations in the configured VOs, which is the basis for any collaboration?
- How to develop and agree on the common principles of sharing and working together in the configured VOs?
- How to quickly reach agreements on the roles and responsibilities of each partner, to reflect their sharing of tasks and the rights concerning the produced results?

To achieve dynamic, fluent and agile formation of the VOs, it is necessary that the potential partners are prepared and ready to participate in such collaboration. This requires the existence of commonality in their interoperability infrastructure, their operating rules and their cooperation agreements, among other aspects. Another requirement for such collaboration is the pre-existence of a basic level of trust among the organisations. In practice, and mostly in new manufacturing areas, these and other requirements necessitated the establishment of a-priori long-term strategic alliances (also referred to as the “breeding environments” for VOs), in order to provide the necessary context for effective dynamic creation of shorter-term goal-oriented networks. The term Virtual organisations Breeding Environment (VBE) representing these alliances is introduced and defined in [14] as follows:

**Virtual organisations Breeding Environment** is an association of organisations and a set of related supporting institutions which adhere to a base long-term cooperation agreement and adoption of common operating principles and infrastructures, with the main goal of increasing their preparedness for collaboration within potentially configured Virtual Organisations.

To comprehensively capture the variety of VBEs’ elements, aspects, functionality, etc., we first look at the VBE reference model in the Sub-section 1.2.1. Following that, the Sub-section 1.2.2. describes in details the four challenges introduced in the last section, and the Sub-section 1.2.3 explains how ontologies present the appropriate base for tackling those challenges.

1.2.1. VBE reference model

A generic reference model is defined for Collaborative Networks [16] to address all their concepts, components, functionalities, processes, etc. This reference model called ARCON (A Reference model for Collaborative Networks) introduces an extendable modelling...
environment, and comprises: (i) a modelling framework and (ii) a set of predefined reference models generated within this framework, each representing a main type of collaborative networks. The VBE (Virtual organisations Breeding Environment) reference model represents one such predefined ARCON reference model [9].

The modelling framework of ARCON for CNs introduces and applies three perspectives, including: (i) CN environment characteristics, (ii) CN life cycle stages and (iii) CN modelling intents. Below these are addressed in more detail specifically in relation to the VBE reference model.

![Subspaces and dimensions in the ARCON reference framework for Collaborative Networks](image)

This Figure illustrates the two subspaces of the CN reference model, namely the endogenous and exogenous subspaces, and their related eight dimensions, which are the main features defining the ARCON reference model. These subspaces and their dimensions serve to classify wide variety of different elements/components of collaborative networks, for instance concerning the VBE environments. Namely, the Figure shows that the “Endogenous Elements” subspace consists of the structural, componential, functional and behavioural dimensions, while the “Exogenous Interactions” subspace consists of the market, support, societal and constituency dimensions.

(i) **VBE environment characteristics.** The VBE reference model comprehensively addresses all heterogeneous elements/components of the VBE environment (as addressed in Figure 1.5). As an instantiation of the ARCON reference models, the VBE components are first grouped into two “subspaces”. The “VBE Endogenous Elements” subspace that represents all elements inside the VBEs and the “VBE Exogenous Interactions” subspace that represents all components outside of the VBE that have close interaction with it. Each subspace is then divided into four different “dimensions”, i.e. the structural, componential, functional and behavioural dimensions for the “VBE Endogenous Elements” subspace, and the market, support, societal and constituency dimensions for the “Exogenous Interactions” subspace. These two subspaces and their dimensions together fully capture and represent all characteristics of the VBE environments. While each of the eight dimensions are briefly described below [17], a more detailed specification of the endogenous element, i.e. the structural, componential, functional and behavioural dimensions, is provided due to their closer relevance to the subject of this thesis.

- **VBE Endogenous Elements subspace:**
- **Structural** dimension addresses the structural composition of the constituting “active” elements of VBEs, namely its participants and their relationships, the roles performed by these elements, and other compositional characteristics of the network, such as its typology, etc.

- **Functional** dimension addresses the “base functions / operations” that must run in the network, as well as the time-sequenced flows of executable actions (e.g. processes) related to different phases of the VBE’s life cycle. The set of methodologies and procedures that run in the VBE are therefore captured by this dimension.

- **Behavioural** dimension addresses the conduct principles and policies, as well as the governance rules that either drive or constrain the behaviour of the VBE and its members over time. Included here are elements such as the principles of collaboration and related rules of conduct for VBE members, principles of trust establishment, contracts, conflict resolution policies, etc.

- **Componential** dimension addresses the individual tangible/intangible elements in the VBE’s network. As such, different resources such as the human elements, software and hardware resources, as well as the information and knowledge are all addressed by this dimension.

  - **VBE Exogenous Interaction subspace:**

    - **Market** dimension addresses the issues related to interactions with “customers”, representing potential beneficiaries as well as “competitors”. Facets related to customers include elements such as transactions and established commitments, marketing and branding, etc. Related to the competitors, issues such as market positioning, strategy, policies, etc. are addressed. Also included in this dimension is the purpose / mission of the VBE, its value proposition, joint identity, etc.

    - **Support** dimension addresses issues related to support services which are provided by the third party institutions (outside of the VBE). The certification services, auditing, insurance services, training, accounting and external coaching are examples of related issues.

    - **Societal** dimension addresses issues related to interactions between the VBE and the society in general. Although this perspective can have a very broad scope, the idea is to model the impacts that VBE has or potentially can have on the society, for example its impact on employment, economic sustainability of a given region, potential for attraction of new investments, as well as the constraints and/or facilitating elements (e.g. legal issues and public body decisions) of the society that affect the VBEs.

    - **Constituency** dimension addresses issues related to the VBE interaction with the universe of its potential new members, i.e. the interactions with those organisations that are not part of the VBE but that the VBE might be interested in attracting. Therefore, general issues like sustainability of the network, attraction factors, what builds / provides a sense of community, or specific aspects such as rules of adhesion and specific “marketing” policies for members, are considered here.

(ii) **VBE life cycle.** The ARCON framework addresses the complete set of life cycle stages of collaborative networks in relation to their environment characteristics. For instance, in the ARCON reference model for VBEs, the VBE environment characteristics are addressed in relation to every phase of the VBE’s life cycle. As such, the VBE reference model represents at which stage of its life cycle specific VBE elements (e.g. specific information repositories or functionalities, etc.) have to be established, specified, activated, or become operational. The VBE life cycle phases are illustrated in Figure 1.6. It consists of three main phases and six related stages. The VBE’s creation phase includes the initiation and foundation
stages. The VBE’s daily business phase includes the operation and evolution stages. And the VBE’s change of nature phase includes the metamorphosis or dissolution stages.

(iii) VBE modelling intents. ARCON captures not only the definitions of VBE’s elements and components, but also how they are modelled, as they may be represented in different modelling systems, such as using the UML diagrams, Petri nets, causal diagrams, etc. For this purpose, ARCON introduces three different VBE modelling intents, namely: the general representation intent (i.e. including the general definitions of its elements), the specific modelling intent (i.e. including detailed conceptual models related to specific aspects of the VBE elements) and the implementation modelling (i.e. including detailed models as implementation specification of each a specific VBE application).

In order to systematise each element of the ARCON reference models, we have introduced a semantic indexing scheme for ARCON [18]. In this scheme, every element introduced within the ARCON framework as well as every specific instantiated element of the ARCON model has an index, which uniquely identifies its location/position within the framework/model.

![Figure 1.6 – Main stages of the VBE’s life cycle](image)

*This Figure illustrates the three main phases of the VBE’s life cycle, including VBE creation, its daily business, and the change of the VBE’s nature. It also indicates their related more detailed stages, including VBE initiation and foundation during the first phase, VBE operation and evolution during the second phase, and VBE metamorphosis or dissolution during the third phase.*

The following Section addresses the endogenous elements of VBEs (namely for the structural, functional, componental and behavioural dimensions of its ARCON’s reference model) in more detail. It specially aims to demonstrate the complexity of these dimensions, which raises a number of challenges for the VBE creation and operation phases.

1.2.1.1. Structural dimension

The generic structure of the CNs, including the main types of its actors, the roles that they can play and the types of inter-relationships among them, needs to be carefully modelled [14] when instantiated to VBEs. Depending on the VBE’s size and domain of activities, the VBE’s structure can become complex and a challenge to its operation stage. The VBE members are typically heterogeneous in terms of their domain of activities, value systems, size and general reasons for their involvement in the VBE. This Section addresses the way in which the structural dimension of the ARCON reference model for VBEs specifies the generic structure of these networks, namely the way it categorises the variety of VBE actors, as well as their roles and relationships.

The VBE actors can be characterised by their following parameters:

a) Level of membership. Two levels of membership can be granted to the VBE members: (i) primary entity, which represents an actor that can have a direct participation in the main business processes, leading to the products or services produced in the scope of the VBE’s
domain; (ii) support entity, which represents an actor not directly involved in the “production” processes, but that performs supporting services to facilitate / enable the normal operation of the VBE, e.g. assisting VBE members with their cooperation preparedness.

b) Role. Depending on the interest and aims of the organisations in the VBE, actors can play different roles. One VBE member can also play several roles in the VBE. Different types of roles that VBE members can play in the VBE include:

- VBE regular member (i.e. the most common role), VBE administrator, VBE advisor, VBE expert (e.g. ontology expert, domain expert), VBE support provider (e.g. Ontology provider, Support service provider, etc.), VBE membership applicant, and VBE customer, as well as the roles that they can play within VOs (e.g. VO partner, Opportunity broker [15], VO planner, VO coordinator).

c) Size. The VBE members can also differ in their sizes, which affects the amount of resources and competencies they can offer to the VBE, and thus their so-called “weight” in the VBE.

d) Value system orientation. By their value system orientation the VBE actors can be divided into the following two types: For-profit entities representing business-oriented companies which provide products and/or services to the market/society, and that get involved in the VOs to gain quantitative benefits. Non-profit institutions representing for example universities, NGOs, environmental support organisations, etc., that get involved in the VOs to gain qualitative benefits.

e) ICT development level and collaboration preparedness. Typically, organisations in VBEs differ by their ICT development level and collaboration preparedness, which in turn also affects how active and dynamic they are within the VBE.

Members can also have a number of different relationships with each other. These include any kind of logical or physical connections or associations established with others, usually referring to some form of interaction, among two or more actors. In the case of VBEs, several relationships can be defined between actors. For each type of relationship and its involved actors a specific network topology (graph) can be represented. The main types of relationship include: cooperation (i.e. the norm in VBEs), collaboration (i.e. the norm in VOs), trusting, specific communication/information flow, exchange/sharing agreements, and control/supervision.

The complexity of the VBE’s structural dimension addressed above may result obstacles to the VBE’s organisational set up. Both primary and support actors need to be aware of all the VBE’s structural organisations in order to better position themselves in the VBE and to achieve maximum productivity.

1.2.1.2. Functional dimension and competency-based VO creation

VBE performs a large number of different types of activities through its entire life cycle. The functional dimension of ARCON addresses the list of the VBE’s activities, as well as the methodologies needed to perform these activities [19]. All VBE activities are basically divided into the following three main types: (i) the background processes of VBE management (e.g. creation of repositories, and bulk registration of participants), (ii) fundamental operational processes of VBE management (e.g. VBE membership management, trust management) and (iii) VO creation management processes (e.g. most-fix partner selection and task planning). These operation together form the VBE management system (VMS). The above three types of VMS functionalities/processes are briefly addressed below:

1. Background processes of VBE management typically take place during the VBE’s creation and change of nature phases. They include processes that are designed to assist the VBE in terms of its maintenance and operations improvement. The main such processes include:
2. **Operational processes of VBE management** take place during the VBE operation and evolution stage of its daily business phase. They are aimed at management of: the VBE members, the VBE information components, and preparing VBE for its main activities, namely the facilitation and support of VO creation. The fundamental processes in this category include:

- VBE membership management (i.e. assignment of roles, rights and rewarding of members)
- VBE members’ profile and competency management
- Management of trust among VBE members
- VO inheritance management
- Management of VBE value system information, management of support institutions information (i.e. information about institutions that can support VBE members with services such as training, accounting, etc.)
- Management of bag of assets information (i.e. the sharing of documents and software of common interest within the VBEs)
- Management of information on VBE’s government and policies
- Decision support management
- Performance management.

3. **VO creation management processes** take place during the VBE operation stage and comprise the main processes of VO creation, including:

- Finding collaborative opportunities (COs) for new VOs
- Decomposition of the identified COs into subtasks, and rough planning of the VOs
- Search for and suggestion of candidate partners for the new VOs
- Negotiation between the VO candidate partners, to finalise the VO establishment

During the VO creation processes, an extensive analysis of certain qualification information related to VBE member organisations is required. When a new CO is identified and characterised, as a first step its specifies the need to be matched against aggregate competency information representing all VBE members, in order to primarily identify if this VBE can address this specific CO or not.

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This Figure illustrates that the product description can be broken down into descriptions of its assemblies, sub-assemblies and components, while the project’s description can be broken down into a set of its constituents, namely activities, sub-activities and tasks.
The CO description is best represented through its two main components of product and project. The product represents the targeted product or service which needs to be produced together with its constituting components. The project specifies the production processes which are needed to develop the targeted product/service, together with its constituting activities [20]. The way a CO is broken down into related products and projects is illustrated in Figure 1.7. The arrows demonstrate decomposition of products and projects into their potential components.

Therefore, a new VO will involve a number of VBE members that can collectively perform all activities/tasks needed for the project, as indicated in the project decomposition, as well as collectively producing all components of the targeted product/service, as defined in the product break-down. Usually, based on the analysis of competency information provided by all members, the VO broker selects the best-fit partners in the VBE for the potential establishment of a new VO. Consequently, in order to increase the chances for participating in VOs, each VBE member should provide relevant information about the activities it can perform and the products/services it can produce/offer, as a part of its organisation’s competency definition. The competency information is therefore the main information required to be collected from the VBE members in order for them to be considered for partner selection and VO creation, and fulfilling the CO’s requirements. Thus, the VO creation within the VBE can be referred to as the “competency-based VO creation”.

Furthermore, in order to garner an invitation/involvement in new VOs, VBE member organisation must keep detailed and up-to-date information about its competencies.

1.2.1.3. Behavioural dimension

This dimension mainly addresses the set of elements which regulate the VBE operation. These elements are classified into four classes:

- **Prescriptive behaviour regulations** – which address normative guidelines or rules for the proper behaviour in the VBE, such as (general) principles, strategies, and protocols. These regulations mainly address the following:
  - Cultural (behavioural) principles, including: regional traditions, business culture and NGO culture
  - Governance principles, including: VBE general member behavioural principles, and domain specific principles
  - Incentive policies and member rewarding

- **Obligatory behaviour regulations** – which set out the rules and principles that must be followed inside the VBE network, such as the working and sharing policies, governance values and the associated enforcement steps. These regulations mainly include:
  - VBE bylaws: e.g. membership policy, financial policies, contract enforcement policy, conflict resolution policy, security issues policy, bylaw amendments policy
  - Internal regulations: e.g. ICT use guideline, rewarding/sanctions principles
  - General law in the VBE region

- **Contracts and agreements** – which represent both the contracts established between the VBE and its external customers, as well as the internal contracts established for VO creation, and cooperation agreements among the network members. These models must have representations that are understandable to both humans and software systems.

- **Constraint & condition** - which represent those VBE environment related features that limit the context of operation for the VBE and its members. These may include: confidentiality constraints, legal constraints, standard constraints, internal normative constraints and physical constraints.
The variety of VBE actors and functionalities addressed in the previous Sub-sections above makes the development of the VBE behavioural regulation elements challenging. Establishment of the government system for every VBE application is both time and effort consuming.

1.2.1.4. Componential dimension

This dimension addresses all resource components accumulated in the VBEs, including the physical resources, ICT resources, human and information resources, as outlined below in more detail.

Related to the subject of this thesis, this Section puts the emphasis on information resources, while these resources also encompass information about the other dimensions of the VBE reference model, namely about the VBE structural, functional and behavioural dimensions. Each resource is briefly addressed below.

- **Physical resources** mainly represent the production equipment needed for the specific application domain of the VBE. In the case of industry networks, it includes for instance the layout of the shared facilities as well as the logistics networks.
- **ICT resources** represent entities characterising the ICT hardware equipment, software and infrastructures used / shared in the network. The software resource also includes the VBE Management System and its subsystems.
- **Human resources** represent the human force available in the VBE network, listed mainly in terms of their competencies, profiles, the potential roles they can perform in VBE, etc.
- **Info / knowledge / asset resources** comprise repositories of information and knowledge and online assets that are shared by the network members or that support the collaboration processes and the networked organisation. They also encompass all data and information accumulated in the VBE management sub-systems, as well as the knowledge acquired and stored by the VBE human resources and other actors, as exemplified below.
  - Data handled by VBE management sub-systems, including:
    - Profile/competency data of VBE members, data related to management of trust of VBE members, information about new and running VOs, etc.
  - Information components stored within the VBE bag of assets to be shared by all VBE members:
    - General VBE characterisation information (e.g. its aggregate competencies) and VBE inheritance information (e.g. the knowledge that will be preserved when a VBE dissolves)
    - Ontologies stored for the VBEs, including the VBE common ontologies and VBE domain related ontologies

Considering the wide variety of information resources needed in VBEs, these resources must be obtained thoroughly and organised carefully, while specialised supporting ICT tools are needed to maintain and analyse this information.

1.2.2. VBE management challenges

Considering the diversity of the VBE endogenous elements, namely the VBE structure, functionalities, behavioural regulations, and resource components (as addressed in Section 1.1 and detailed in Section 1.2.1), the creation and operation of VBEs are challenging. The experience of the currently running VBEs demonstrates that these challenges even cause failure of the VBEs.
In Section 1.1 we have briefly introduced four main challenges, which in this thesis will be further addressed, which are also illustrated in Figure 1.4. Below this Section presents a more detailed specification of these challenges.

1.2.2.1. General description of the four challenges

Addressing these four challenges through introduction and provision of new approaches, models, mechanisms and tools is the main motivation behind the research addressed in this thesis. Table 1.1 briefly outlines the four challenges, while more details about every challenge are addressed below in this section.

**Challenge I - Establishing common understanding of VBE aspects.** Common understanding of both the general (domain and application independent) and the domain-related VBE concepts is the basic requirement for effective cooperation and collaboration among its members. VBEs accumulate wide variety of knowledge, including the general/common knowledge, as well as the domain/business area knowledge, which needs to be commonly understood, processed and/or analysed. To facilitate interoperability and smooth collaboration, all VBE stakeholders must use the same definition for common concepts, and have the same understanding of different aspects related to the VBE, including: VBE’s aims and activities, policies, membership regulations, working/sharing principles, VBE member competencies, performance measurement criteria, and many others.

There is still a lack of consensus on the coherent definitions and terminology addressing common concepts and generic intra-VBE structures and operations. Many general VBE concepts are still vaguely defined and the same terms are being used with different meanings, resulting in confusion in communication and co-working [11]. In our empirical case study, which involved eight VBEs (as addressed in Annex C), the VBE representatives unanimously identified the disadvantage of lacking common conceptual understanding within their networks and the importance of establishing such commonality in the network. They have also emphasised that this problem becomes more severe when new organisations dynamically join the VBE (e.g. when new organisations joins the VBE from different geographic region, or when a new VBE support institution e.g. an insurance or training organisation joins the VBE to provide some services to VBE members).

Besides the need for intra-VBE commonality, some inter-VBE commonality must also be achieved. Using and sharing common VBE terminology among different VBEs is challenging. Often representatives of existing VBEs face difficulties in reusing experiences and results from one another, through both oral communication and exchange of text documents, as it is expressed by participants in our VBE survey.

*Therefore, identification and specification of common generic VBE terminology, as well as development of common semantic description for VBE information/knowledge is required.*

**Challenge II - Reusing VBE information system and mechanisms, when instantiated to different domains.** New VBEs are being created and operated in a variety and range of domains and application environments, e.g. from supporting the provision of business services, and product design and manufacturing to the management of natural disasters, and facilitating scientific virtual laboratory experimentation, among other areas. Clearly, each domain/application environment has its own features, culture, terminology, etc. that shall be considered and supported by its VBEs’ management systems.

Typically when a new VBE is created, a large amount of time, effort and resources are applied for development and parameterisation of the new VBE management system. Lack of resources, time and effort needed may stop the creation process of a new VBE.
Table 1.1: Summary of the VBE challenges addressed in this thesis

<table>
<thead>
<tr>
<th>Challenges / Characteristics</th>
<th>Meaning and importance</th>
<th>Summary of findings from empirical case study</th>
<th>Identified approaches to respond to challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>I – Establishing common understanding of VBE aspects</td>
<td>Common understanding is the required base for collaboration in networks</td>
<td>There is a lack of common understanding about the existing VBE concepts and the new VBE terminology: introduced in research: - by new members of VBEs - among different VBEs</td>
<td>A dictionary/glossary/ontology of VBE concepts is vital for this environment</td>
</tr>
<tr>
<td>II – Reusing VBE information systems and mechanisms, instantiated in different domains</td>
<td>VBEs information systems need to be installed and operating in various domains of activities</td>
<td>In current VBEs: - Very large amount of time/effort is spent on creation/parameterisation of new VBE information systems: - There is a lack of generic reusable systems for VBE creation</td>
<td>Some generic VBE related information models and mechanisms should pre-exist, namely: - generic information models for VBE element and concepts - domain-dependent information classifications - generic mechanism to maintain and manipulate data</td>
</tr>
<tr>
<td>III – Supporting dynamism and scalability of VBEs</td>
<td>Frequent changes in the market/society demands fast changes in VBEs and its member organisations</td>
<td>Traditional (mostly manual) methods, currently used for management of evolving information are ineffective</td>
<td>Automated and semi-automated approaches and software tools are fundamental for dealing with VBE dynamism and scalability</td>
</tr>
<tr>
<td>IV – Facilitating the balancing and boosting of VO involvement for VBE members</td>
<td>Involvement of VBE members in VOs must be fair and percentage of success in VOs created within VBEs needs to increase</td>
<td>Traditional methods of VO creation in VBEs are ineffective, due to the following: - VBE members do not know each other’s capabilities - traditional (e.g. manual) matching of VBE members against collaborative opportunities (best-fit VO partners selection) are ineffective - limited mechanisms are applied for evaluation of organisations’ suitability for collaborative networking - VBE members are not directed towards new customers through the Internet</td>
<td>Digital and advanced maintenance and management of comprehensive VBE members’ characteristics is mandatory in this environment</td>
</tr>
</tbody>
</table>

For example, during the creation stage of the VBE, several databases need to be created to support the storage and manipulation of information/knowledge which will be handled by different VBE management sub-systems. Considering the large variety of the VBE’s
information which needs to be managed during the VBE operation phase, the pre-existence of common reusable VBE management system as well as semi-automated mechanisms supporting database design, development and parameterisation would effectively assist creation of new VBEs and significantly reduce the needed resources, time and effort. Furthermore, during the VBE’s creation stage, parameterisation of its management system to reflect both its generic characteristics as well as its specific domain-related and application-related characteristics are required. For instance, the members’ roles, governance principles, and assets supported by the new VBE need to be specified, as well as the competencies, practices and resources needed in this new VBE, among many others. Due to the lack of commonly available standards, at present every new VBE needs to start from scratch and individually invest in creating and evolving its data/knowledge specification and classifications. During our empirical case study (as addressed in Annex C), the VBE representatives unanimously identified the difficulty of such tasks and the benefits they can gain from the reuse of pre-existing information specifications/classifications related to their VBEs.

Therefore, development of reusable VBE management system and approaches for instantiation and adaptation of the reusable VBE management sub-systems to different domains / areas of activities is required, and their semi-automation is desired.

Challenge III – Supporting dynamism and scalability of VBEs. Frequent changes in the market and society, such as the emergence of new customer demands or new technological trends, drive VBEs to work in a very dynamic manner. Supporting dynamic aspects of VBEs generates a number of requirements, e.g. it requires that the VBE management system is endowed with specific functionalities to support the human actors in VBEs in coping with necessary changes in the environment. Furthermore, the VBE management system needs to be adaptable, customisable and extendable when necessary, in order to cope with changes that cannot be predefined or predicted. Also, in order to obtain the new needed competencies or resources in the VBE for addressing new emerged opportunities in the market or society, the number of VBE members shall increase. This increase happens sporadically or intensively during the VBE evolution time. Nevertheless, with every new VBE member, its information shall be processed, e.g. in order to both classify and extract the necessary general information about the VBE members and to extend the aggregate VBE competency catalogue, and this should occur in a very dynamic manner. Clearly, manual processing of new VBE members’ information in a dynamic manner is not efficient and is error prone.

In our empirical case study of 1st generation VBEs (as outlined in Annex C), VBE representatives have unanimously identified the need for improvement in the process of collection and analysis of information related to the VBE members. For example, specific functionalities are needed for processing the competencies of VBE member organisations, including: the categorisation and analysis of VBE member competencies, classification of different competencies into catalogues and search for competencies in VBEs versus the criteria specified in the emerging collaboration opportunities (e.g. the call for proposals). While some of these functionalities can be automated (e.g. cataloguing the competencies), others require support with semi-automated tools. For example, supporting the dynamic nature of VBEs, that can continuously accept new members, extending the competency catalogues and keeping it up-to-date needs to be supported semi-automatically.

However, in order to be processed by semi-automated software tools, the wide variety of VBE information needs to be formally represented, categorised and digitised. There is still a lack of such formal representation, categorisations and digitisation in practice.
Therefore formal modelling and specification of VBE information, as well as development of semi-automated approaches for speeding up the VBE information processing is required to effectively support its dynamism and scalability.

Challenge IV - Facilitating the balancing and boosting of VO involvement for VBE members. The main aim of VBEs is the fluent configuration of Virtual Organisations to enable its member organizations with taking advantage of the emerging opportunities. However, currently VBEs often fail to effectively address the emerged collaborative opportunities due of the following main reasons:

First, in medium size VBEs (i.e. VBEs with more than 30 members) or larger ones, organisations often do not even have the possibility to properly get to know each other and learn about each other expertise and potential, which in turn prevents them from collaborating. As VBEs are typically composed of distributed companies, each with highly specialised knowledge, skills and technologies, they need to enable these diverse and distributed organisations to bridge their differences in the creating new shared perspectives. According to [21], inter-organisational learning happens in two ways: either through (1) transfer of existing knowledge from one organisation to another, or (2) through the creation of new knowledge that is jointly developed and shared. Therefore, gathering, organising, aggregating and sharing of the basic characteristic information about VBE members (e.g. their contact data, industry sector, vision, competency, etc.) is a critical instrument for supporting collaboration among VBE members. At present however, due to lack of conceptual approaches, and considering the heterogeneity among VBE member organisations (such as differences in their sizes, computer skills, expertise, domain/business areas, etc.) the application of some form of automation to gather and organise their characteristics/information in a uniform way is challenging.

Second, in order to fairly select most-fit organization for involvement in a new VO, VBE members must provide detailed up-to-date information about their competencies. For this purpose, in our research, we have identified that the competency-related information typically needed from every organisation includes: accurate description of the member’s capabilities, its free resources’ capacities, the production costs for each product, as well as conspicuous proof of the validity of all provided information. Based on the analysis of such competency information provided by all members, the VO brokers can then select the best-fit partners for each new VO. In small VBEs, the competency information may even be only orally communicated from the VBE members to the VBE administrator and/or the VBE coach. However, in medium and large VBEs, depending on the organisation’s complexity, and especially in the dynamic VBEs – with continuous adjustment of VBE member competencies to the changing conditions in the market/society – gathering and analysis of competency information by human actors in the VBE is error prone and not effective. In such VBEs, new ideas and mechanisms for competency management are required. Both the literature and case studies have identified the lack of proper competency management approaches for VBEs, as well as the lack of VBE member competency models. At present, the mere definition of a member organisation’s competency is difficult, since competency is generally considered as “tacit knowledge”, hard to comprehensively capture, model, and represent.

Third, in order to form a strong VBE that capable of addressing a sufficient number of collaborative opportunities, each VBE member shall be evaluated before it is allowed to participate in VO configuration activities. Our empirical case study shows the need for personal contact with members of organizations when it is needed to check the organization’s competency. The 1st generation VBEs lack an up-to-date digital collection of members’ competency information, in order to carry out their evaluation for VBE.
Fourth, in order to generate more opportunities for the VBE, the VBE administration should introduce/advertise the VBE as a collective representation of all its members' competencies and all its abilities and resources, to the market/society and its potential customers. Our empirical case study of 1st generation VBEs has identified that at present, the VBE administrator personally meets with potential customers, for example at the fairs, to present some general aspects about the VBE and its activities. The VBE representatives have stated that they need approaches and instruments for advertising online and providing the accurate detailed information about the VBE’s capabilities, capacities, etc., for producing specific products or services.

Therefore, to boost VO creation, innovative approaches for modelling, management and presentation of the VBE’s characteristics as well as its members’ characteristic information in digital format is required to promote the VBE in the market/society and towards its customers.

Figure 1.8 - Projection of the four VBE challenges into VBE information modelling and management aspects

This Figure illustrates further projection of the four VBE challenges into their information modelling and management aspects in VBEs. Namely, addressing every challenge in terms of more specific challenges.

1.2.2.2. Further projection to VBE information modelling and management

We have done a more detailed analysis of the four challenges specifically in relation to the need for information modelling and management in VBEs, as illustrated in Figure 1.8 and described in this section.

In terms of the VBE information modelling and management, for the 1st challenge, we first need to address standardisation of VBE terms. We then need to develop an effective approach to support VBE members with learning about the VBE terminology. Furthermore, we have to support interconnections or integrability of various kinds and groups of terms...
represented in VBEs. And we also need to represent the knowledge about VBEs in such a way that it can be transferred to other VBEs or organizations for legacy support systems purposes.

In order to address the 2nd challenge, some catalogues of domain terminology should be defined prior to establishing VBEs in a domain. Furthermore, in order to establish VBEs uniformly in different domains, some generic VBE information models, common to all VBEs, should exist. In order to support the agility of ICT infrastructure set-up in every new domain of VBE activities, the main database schemas for the VBEs should be predefined and thus pre-exist. However, these database schemas should be easily extendable to support specificities of new VBE application domains.

In order to address the 3rd challenge, some intelligent approaches for semi-automated information discovery and processing must be developed. In its turn, the classification and presentation of the VBE information and data should support these semi-automated processing.

In order to address the 4th challenge, the most efficient way of homogeneous representation of VBE members’ information (namely, the VBE members profiles and competencies) shall be developed.

1.2.3. VBE-ontology and ColOnto system

The research performed by this thesis addresses the design and development of a unified VBE-ontology, as well as ontology engineering mechanisms to directly tackle the challenges listed and described above in Section 1.2.2.

Ontologies provide the classical means for conceptual representation of knowledge, such as specification, conceptualisation, annotation, generalisation and mapping of information/knowledge classes. Engineering of ontologies using standard ontology languages, such as Web Ontology Language (OWL) [22] provides formalism [23] and uniformity to conceptual knowledge representation. Our specification and engineering of “one” unified ontology for the specific domain of VBEs provides unified and common conceptualisation of this domain.

The way in which the VBE-ontology addresses the previously mentioned four challenges is illustrated in Figure 1.9, and described below in this section.

Specifically, the development of our unified VBE-ontology helps responding to Challenge I - on common understanding as follows:

- The VBE-ontology represents a single point of reference for concepts and terms, as well as their definitions, abbreviations, and synonyms. This means that:
  - The VBE-ontology serves as the primary container of standard representation of VBE concepts.
  - The detailed annotations of VBE concepts, such as labels, synonyms, definitions, and abbreviations support VBE members with learning about a specific VBE concept.
  - Addressing the wide variety of VBE concepts in one unified VBE-ontology supports integrability among all concepts.
  - Using the same VBE-ontology by different VBEs supports transferability of the VBE information from one VBE to another VBE.

In relation to Challenge II - on reusable VBE information systems and their instantiation, the VBE ontology addresses it as follows:

- The VBE-ontology supports cataloguing of domain-related terms.
- The uniform VBE-ontology supports a uniform representation of VBEs from different domains.
- The VBE-ontology is a base for other information or data models and we also apply existing techniques for semi-automated conversion of ontologies into database schemas [24]. This supports the database development process during the VBE establishment stage.
- Integration of the common VBE concepts with the domain concepts into one unified ontology supports extendibility of common VBE information models with their needed domain-related counterparts.

In relation to Challenge III - on VBE dynamism and scalability, the developed VBE-ontology responds to it in the following manner:
- Formal representation of the knowledge in the VBE-ontology facilitates semi-automated processing of this knowledge through software tools. The ontology itself can be used to support the semi-automated knowledge discovered and extraction from the text-corpora about the organizations [25][26].

![Figure 1.9 – Addressing the four challenges by the VBE-ontology](image)

*This Figure illustrates the way in which a unified ontology for VBEs addresses and support the four main VBE information modelling and management challenges. As such, the VBE-ontology provides the formal, uniform, homogeneous, semantic, and extendable specification of the VBE information. It also represents a single point of reference for addressing the specification of VBE concepts and terminology.*

In relation to Challenge IV - on balancing and boosting VO involvement, the VBE ontology addresses it as follows:
- The VBE-ontology provides uniformity and homogeneity in representation of VBE information, including the member organizations’ information. In addition to that it supports:
Modelling organisations’ profiles and competencies in VBEs, within the VBE-ontology, supports digitalising the VBE members’ characteristics (such as the name, address, size, area of activities, etc.) which facilitate automating the VO creation, and supports activities, such as familiarisation of VBE members with one another, promoting the VBE to its potential customers and evaluation of VBE members’ for their preparedness and readiness to collaborate.

Uniform digital representation of VBE members in the VBE through their profiles in turn smoothens their differences, and supports a more balanced involvement in potential VOs.

Digitalising the “competency” related information (such as members’ capabilities and capacities) supports automation of the VO creation process by facilitating the process of matching the VBE members’ competencies against the characterisation of Collaborative Opportunities; while digitalising the rest of “profile” data supports selection of the best-fit VO partners.

In order for VBEs to fully benefit from their specified ontology, a number of functionalities for ontology engineering and management need to be developed. As planned in our research, ontology engineering functionalities shall support the discovery actions and evolution of the VBE-ontology itself. Also, as planned, the ontology management functionalities shall support the VBE stakeholders with their learning about the VBE concepts, shall preserve the consistency among different VBE databases and their domain parameters with the VBE-ontology, and shall perform semi-automated information discovery from the VBE environment. All of these functionalities, which are required for VBE management support, are designed and prototypically developed within the Ontology Discovery and Management System (ODMS), as described in Chapter 4.

![ColOnto – conceptual part](image1.png)

![ColOnto - functional part](image2.png)

**Figure 1.10 – Two main modules of the ColOnto system**

This Figure illustrates the two main modules of the ColOnto system, which are suggested in this thesis to address four main VBE challenges. Its conceptual model addresses the VBE-ontology specification, which also includes the profile and competency models, incorporated within this ontology. Its functional module consists of the system called the Ontology Discovery and Management System (ODMS). The ODMS is developed on top of the VBE-ontology and is aimed at maintenance and management of this ontology. A sub-system of the ODMS consists of the Profile and Competency Management System (PCMS), specifically aiming at the management of the profile and competency models and data related to VBE member organisations.

More specifically, in order to handle the profile and competency of VBE member organisations due to the specific role played by them inside the VBEs, as planned in our research, a number of maintenance and management functionalities are designed and
developed focused on supporting and manipulation of the profile and competency information and knowledge. As such, the maintenance functionalities support the creation and manipulation of basic collection of profiles and competencies in digital format, while after management functionalities provide user-friendly processes needed for boosting the VO creation. These use-based processes shall support: (i) viewing of VBE member profiles and competencies in order to aid VBE members in getting familiar with one another, and (ii) representing the aggregated view of members’ profiles and competencies, to support the promotion of VBE towards customers, searching for collaborative opportunities and retrieval of profile and competency information to help match VBE members’ characteristics against collaborative opportunities that have arisen. The required profile and competency maintenance and management functionalities are further addressed in this thesis in Chapter 4 as they are developed within one VBE subsystem called Profile and Competency Management System (PCMS).

In order to develop a comprehensive solution to the four main addressed Challenges, in this thesis we introduce a system called ColOnto (Collaborative networks Ontology system. The ColOnto system is represented by its two main modules, namely: (1) a conceptual part, consisting of the VBE-ontology and (2) the functional part consisting of the set of functionalities required for the VBE-ontology maintenance and management. These two modules are illustrated below in Figure 1.10.

1.3. Research motivation and problem area description

This Section first presents and summarises the background for the research and development of ontologies for VBEs, as well as for the VBE profile and competency modelling and management. Then it presents the main related research problems that are identified.

1.3.1. Research background

Although the need for ontology development and management to support Collaborative Networks and VBEs is identified in previous research [27][28], progress in this area of research is still at its early stages. Only a small number of publications exist close to our work, which have mainly focused on the following three topics:

- **An empirical development of an ontology for VBEs.** An early attempt to address an ontology for VBEs is presented in [29]. This ontology is limited and aims to provide some commonality among VBE members. It is called the “CNO ontology” and only briefly addresses the VBE as a subclass of the Collaborative Networked Organisations (CNOs). It includes a narrow subset of the VBE related top-level concepts, such as “VBE”, “VO”, “Organisation”, and “VBE Member”, providing their limited definitions and inter-relationships.
- **A sub-ontology for specific VBE management subsystem.** An ontology for the VBEs’ Performance Indicators (PIs) and the VBEs’ Collaborative Opportunities (COs) called the ‘PI and CO Ontology” is presented by [30]. The main concepts in this ontology include: “PI”, “CO”, “Organisation”, “VBE”, “VO”, “Performance requirement” and “Measurement objective”. This ontology is specifically developed to support the measurement of the performance of VBE member organisations primarily needed to select the most-fit VO partners. A software tool implemented on top of this ontology provides the functionality for annotation and searching of PIs.
- **Ontology library for VBEs.** In [31] the general concept of an Ontology Library System (OLS) which is introduced in [32] is further adapted for the case VBEs. The OLS is defined as “an important tool in grouping and re-organising ontologies for reuse, integration, maintenance, mapping and versioning”. Namely, the OLS offers
the following three groups of functionalities: ontology management, ontology adaptation and ontology standardisation (as addressed in Section 2.2.3.1 in more detail). However, while this research applies the OLS to VBEs, it does not in fact specify the VBE ontology itself.

In relation to our profile and competency partition of the VBE-ontology, while there are significant numbers of research publications addressing the general topic of competencies of people, mainly within the human resources management area, there is a limited number of research addressing competencies of organisations, especially within the context of organisations’ networking. Existing competency definitions and models each address different constituting components, depending on the context for which they are developed. Research and development on generic profiling for organisations are also very limited. The existing organisations’ profiling is represented by individual practical cases. While the related research and practice on profiles and competencies, that are not specifically related to CNs and VBEs in particular, are addressed in the next Chapter (in Sections 2.2.4 and 2.2.5), our main findings on VBE-related profiles and competencies are addressed in the following three groups:

• **Organisation “competency models” for VBE members.** In [33] a competency model for “clusters of manufacturing organisations” is addressed, which aims to support the automation of VO formation within this cluster. The introduction of this model was the first step towards competency-based support for boosting the VO creation, but the model is not generic enough to be adapted to the variety of different VBEs. In [34] and [35], another competency model for networks of organisations is introduced, which is not aimed at facilitating the VO creation, but rather to “increase and extend” competencies themselves within individual firms. Section 2.2.4 addresses competency models in more detail.

• **Requirements for “competency management” in VBEs.** In a number of past research [14][36][37] the need for competency management functionalities as a subsystem of the VBE management system is identified (as also addressed in Section 2.2.5 in more detail). These functionalities include: competency appraisal, competency gap analysis, competency-based marketing support, and development of new core competencies in the VBE, among others. However, while some of these functionalities are identified in previous research, they are not further specified or developed.

• **Profile and competency management in currently running VBEs.** A few existing VBEs handle digitised profiles and competencies of their members (see more details in Section 2.3). Furthermore, while every VBE stores profiles of their members, which represent a variety of characteristics about their member organisations, only a few have a limited model of competency and store some details about competencies of their members. In other words, an organisation’s competencies are typically drawn up and generated through defining companies’ products, processes, and resources. Moreover, every VBE individually invests into development of its proprietary management subsystems for handling their members’ profiles and competencies. This indicates the lack of generic and comprehensive models and approaches for profile and competency management that can be applied to the existing VBEs.

**1.3.2. Research problem areas**

The overview of the research background presented in this thesis demonstrates the significant gaps existing in areas of VBE ontologies, as well as incomplete ontologies for VBE members’ profiles and competencies. Based on these, the thesis identifies four open problem areas which are addressed within its scope, including:
1. Systematic design and development of the VBE-ontology. In order to develop a VBE-ontology that can be shared by different actors for different purposes, including its collective management, maintenance and extension, the VBE-ontology first needs to be carefully designed. Therefore, a systematic approach to design and further develop of the VBE-ontology needs to be defined and applied while responding to the following questions: Should there be one VBE-ontology or a set of ontologies? Which areas of VBE related knowledge and information should be addressed by the VBE ontologies? Should the VBE ontologies be formal or informal? What are the sources of information needed for development of the VBE ontologies? Which existing ontologies can be reused for building the VBE ontologies?

2. Maintenance and evolution functionalities for VBE-ontology. The VBE-ontology needs to continuously evolve both to reflect the new findings in the VBE area of research and to cope with the changes in the VBEs due to market and society dynamism. Since the VBE-ontology shall be used by a large number of users, its dynamic collective maintenance and evolution are challenging. Therefore, a system providing access to the VBE-ontology needs to be developed, which also supports tracing the changes/extensions done in the VBE-ontology and its versioning. The thesis addresses the following four specific functionalities for this purpose:

- Ontologies library. If the VBE has a number of ontologies, there is a need for a library system facilitating access to these ontologies by human and software agents.
- Collective development of ontologies. The common ontologies for VBEs shall be collectively developed and evolved by its various actors. Therefore, an approach to support simultaneous access to the VBE-ontology needs to be developed.
- Semi-automated ontology discovery. Mechanisms shall be developed to support continuous dynamism and evolution of the VBE-ontology. This ontology can be discovered from many sources, e.g. the existing databases at the member sites, websites, online brochures and advertisements available about the members, and online forms and documents existing at each organization in different formats, e.g. database schemas, structured text (e.g. HTML), unstructured text, etc. Development of such mechanisms is challenging and also raises the following questions: Which semi-automated techniques can be developed for ontology discovery that can also be reused? What sources can be used to discover concepts of the VBE-ontology be found?
- Semi-automated integration of related ontologies. For development and extending of some partitions in the VBE-ontology, a number of existing related ontologies from the same domain must be found to be reused. Thus, a special mechanism shall be developed to support the engineering and evolution of the VBE-ontology through integrating other ontologies into it.

3. VBE ontology-based management functionalities. A number of ontology-based functionalities need to be developed to support the VBE through its entire life cycle from its creation stage to its dissolution stage, aimed mainly at both coping with the large amounts of information to process, and accelerating the VBE management operations. The thesis addresses following main functionalities for this purpose:

- Establishing of common understanding. Supporting this functionality calls for development of a graphical user interface for the VBE-ontology, to be accessed by all stakeholders to familiarise themselves with VBE concepts. Development of an easily navigable interface is required. First, the requirements from different stakeholders navigating the VBE-ontology need to be analysed. Then, the GUI shall be realised satisfying those needs.
o **Instantiating VBE to different domains.** This functionality needs above all the development of a software interface for the VBE-ontology, which provides some restrictions on the uniformity and formal expression level of the VBE-ontology. A specific mechanism shall be developed which, when using the VBE-ontology, can customise and parameterise the generic VBE management subsystems to each specific VBE environment. The following questions must also be answered: How can the VBE-ontology be developed so that it can be easily converted into database schemas for different VBE management subsystems? What specific features are needed for the VBE-ontology in order for it to be used for parameterisation of different VBE management sub-systems?

o **Supporting dynamism in VBEs.** For this functionality the VBE-ontology shall provide operations supporting both the semi-automated dynamic information discovery and management, as well as some semantic mechanisms, i.e. semantic-based search mechanisms that accelerate the execution of information management operations. As such, some existing approaches (e.g. an approach for ontology-based information discovery from text-corpora) shall be adapted to support this purpose, and a constant connection between the VBE management sub-systems and the VBE-ontology shall be established. Prior to this, the following questions need to be answered: How to make the VBE-ontology easily reusable within by a number of software tools (e.g. the VBE management subsystems)? How can one trace the correspondence between the VBE-ontology and the information stored internally within the VBE software tools?

4. **Ontology visualisation.** Visualisation of the ontologies is challenging. Most ontology viewers typically locate ontology classes through their hierarchical (i.e. subclass-superclass) relationships with other classes. However such an approach for locating ontology elements is often not convenient or user-friendly for human VBE actors who wish to learn about the entire network of VBE concepts and the relationships among them (e.g. including part-of relationships). Furthermore, the VBE-ontology is large, with concepts described by a number of attributes and relationships with other concepts. Therefore, existing approaches for visualisation of ontologies, including catalogues, graphs, etc., shall be considered in order to select a suitable approach for visualisation of the VBE-ontology.

In relation to the **profile and competency** partition of the VBE-ontology, open problem areas of research include the following:

a. **Establishing unified/generic models.** The profile and competency models included in the VBE-ontology need to be generic in order to suit every VBE regardless of its domain and application area. Some challenges in such models are related to **unification of different existing models of competency.** Traditionally, every cluster/VBE has introduced a different model, with different elements and formats representing its competencies. There is also no uniformity in the literature related to modelling competency presenting it. Specification of a unified/generic model for VBE competency is a necessity at least to support its processing by different VBE subsystems, if not also to simplify the processing by human actors in the VBEs.

b. **Continuous update of profile/competency data.** In today’s dynamic market, a large number of an organisation’s characteristics, such as their resources (human, machinery, etc.), position in the market, financial status, organisation’s aim/strategy, details of its products, associated partners etc., are not static and subject to changes at different times during the life cycle of the organisation. Therefore, people who represent VBE organisations, as well as those who represent the VO networks established within the VBEs, face the difficulty of
continuously providing new up-to-date data about their organisations/networks, which is time
and effort consuming and not feasible for SMEs. Automating a large part of this task is
possible, albeit challenging.

c. Handling the confidentiality of profile/competency data. While a part of the profile
data of each organisation is public knowledge, another part of it needs to be handled as
proprietary, e.g. the financial data and market strategy of the VBE member organisations.
Merely adding of private, restricted and public categories (as applied to file systems) on top of
the profile data is not sufficient. Different levels of authorisation must be defined on
accessing/updating elements of the VBE organisation profiles. These levels shall be granted to
different requesters/actors in the VBE, depending on the roles they are assigned. The roles in
VBEs are dynamically assigned to actors by the VBE administrator.

d. Maintenance and management of VBE profiles. The profile and competency
models should support the VBE management functionalities/operations, which are mainly
aimed at boosting the VO creation. These include collection of up-to-date profile and
competency data, navigation of profile/competency data, and their search and retrieval.
The above types of functions require both graphical interfaces for human actors as well as
software interfaces. The software interfaces are used by other VBE management subsystems
to manipulate profile and competency data.

e. Generic competency naming. With the lack of standards for naming of
the competencies in different domains and applications, it is challenging for VBE
organizations to specify and describe their competencies. Nevertheless, the problem of
naming and developing taxonomy for the existing and emerging competency names in
different domains and applications is outside the scope of our research. Nevertheless, though
in ontology different names assigned to the same competency can be recognized through their
definitions and thus connected within the VBE-ontology.

f. Cataloguing competencies. Automated and manual classification of the wide variety
of existing competencies in the world, even if limited to a specific domain and application
area is still challenging. So far, there are no standards defined for classification of
competencies, and every day new competencies emerge in many domains and application
areas. In practice, every VBE (typically small clusters) develops its own very small base
competency classification that it uses manually to match VBE competencies against
the criteria required in emerging opportunities, e.g. the calls for tenders. Managing
competencies in large networks (even more than 50 organisations) calls for formalisation of
competencies and semi-automation of their classification in uniform manner, with
the involvement of human experts.

1.4. Summary of research objectives and research questions
for the thesis

The main research objective for this thesis is to specify and develop the ColOnto system in
order to address the four mentioned challenges for VBE information modelling and
management, as introduced in Section 1.2.2. We further split this objective into two specific
conceptual objectives (RO1 and RO2) and two specific functional objectives (RO3 and RO4)
as follows:

1. Conceptual research objective RO1: Design and development of the VBE-ontology.
   This includes definition of the scope, specification of the design, and building the first
   version of the VBE-ontology.

2. Conceptual research objective RO2: Design and development of suitable models for
   profile and competency of VBE member organizations. This includes detailed
   specification of the profile and competency models within the VBE-ontology.
3. **Functional research objective RO3**: Development of Ontology Discovery and Management System. This includes specification and development of functionalities to support: establishing common understanding of VBE aspects, VBE instantiation in different domains, and dynamism and scalability in VBEs, as well as implementing a prototype of ODMS.

4. **Functional research objective RO4**: Development of Profile and Competency management System. This includes specification and development of functionalities to support balancing and boosting partners’ VO involvement within VBEs, and implementing a prototype of PCMS.

As a part of addressing the four research objectives mentioned above, we carefully address each research problem areas presented in Section 1.3.2, specifically:

- **Our research results on VBE-ontology and ODMS addresses**: systematic design and development of the VBE-ontology, maintenance and evolution functionalities for VBE-ontology, VBE ontology-based management functionalities, and ontology visualisation, among others.

- **Our research results on profiles & competencies and PCMS addresses**: establishing unified-generic models, semi-automated continuous update of profile data, handling the confidentiality of profile data, maintenance and management of VBE profiles, generic competency naming, and cataloguing competencies, among others.

Through the approach we introduce for addressing the four research objectives, we answer the main (general) research question (GRQ) for the thesis as follows:

**GRQ.** Can we effectively specify an ontology for the Virtual organisations Breeding Environment (VBE), as well as develop semi-automated ontology-based functionalities to support VBEs, such that they can respond to the following four challenges of:

1) establishing common understanding of VBE aspects,
2) reusing VBE information systems and mechanisms, instantiated in different domains,
3) supporting dynamism and scalability of VBEs, and
4) facilitating the balancing and boosting of VO involvement for VBE members?

This GRQ is further refined into three more specific questions (RQ1 to RQ3). The RQ1 addresses the definition task of VBE-ontology and particularly introduces the need for definition of the profile and competency models within the VBE-ontology.

**RQ1.** Can we identify the scope and elements of the ontology encompassing wide variety of VBE related entities and concepts, so that it represents the inherent diversity in its subspaces, addressing all endogenous elements and exogenous interactions of the VBE reference model, and specifically the subspace of profile and competency management?

The RQ2 addresses both the logical and physical organisation of the VBE-ontology. Particularly it introduces the manner in which this physical/logical organisation responds to identified challenges for VBE-ontology development. Furthermore, it exemplifies the specification of the VBE profile and competency models within it.

**RQ2.** Can we capture, organise, and specify the large set of diverse but interrelated aspects identified in RQ1 within the VBE-ontology, considering both their evolutionary nature and the heterogeneity of their sources?
The RQ3 addresses the required ontology management functionalities to be developed on top of the VBE-ontology. These functionalities are mainly divided into two main groups: (i) functionalities for maintaining the VBE-ontology itself, and the VBE-ontology-based support functionalities, (ii) functionalities is specifically aimed at supporting profile and competency management in VBEs.

**RQ3.** Which set of functionalities are needed to maintain (e.g. discover, engineer and integrate) the continuously evolving VBE-ontology, as well as the semi-automated management of the information supported through the VBE-ontology?

### 1.5. Research and development methodology

The methodology addressing design and development of the ColOnto system for VBEs consists of three main phases of “Gathering background input”, “ColOnto design & development” and “ColOnto Validation”. These phases are further described below.

- **Phase 1: Gathering background input**
  - **Step 1.1:** Analysis of state of the art in research - to develop the ColOnto system for VBEs to position among the competing research and practices.
  - **Step 1.2:** Analysis of state of the art in practice - through contacting several existing 1st generation VBEs, and collecting information through questionnaires.
  - **Step 1.3:** Requirements analysis - identification of VBE stakeholders’ requirement from running VBEs, as well as and some general VBE requirements obtained from the literature.

- **Phase 2: ColOnto design & development**
  - **Step 2.1:** Conceptual design of ColOnto - aimed at the development of the conceptual specification of the VBE-ontology.
  - **Step 2.2:** Functional specification and development of ColOnto - aimed at the development of functionalities for management of the VBE-ontology.

- **Phase 3: ColOnto validation** - through some empirical and some rational approaches.

### 1.6. ECOLEAD project

The research addressed in this thesis is conducted for the most part within the FP6-IP project ECOLEAD (April 2004 - June 2008) funded by the European Commission [38], with more than twenty research, academic and industry partners. This Section briefly describes the main aspects of this project.

The name “ECOLEAD” stands for “European Collaborative networked Organisations LEADership initiative”. This project aimed to create the strong foundations and mechanisms needed to establish most advanced collaborative and network-based industry society in Europe. The main goals of the ECOLEAD project were specified based on two earlier road-mapping projects on collaborative networks, i.e. the two European IST projects called VOMap [39] (duration 2002-2003) and THINKcreative [40] (duration 2001-2004).

The research and development work in ECOLEAD is primarily focused on five different areas, as shown in Figure 1.11, including the three “vertical areas” of: (1) Virtual Organisations Breeding Environments, (2) Dynamic Virtual Organisation management and (3) Professional Virtual Communities, and the two “horizontal areas” of: (4) the theoretical foundation for collaborative networks and (5) the ICT infrastructure [41].

A summary of the main achievements in the five abovementioned areas of ECOLEAD in more detail are provided in [42]. Please note, that the research results presented in this
thesis are primarily related to the focus area (1) VO Breeding Environments of ECOLEAD project.

(1) VO Breeding Environment. This focus area of ECOLEAD is aimed at understanding, and comprehensive, generic and domain-independent specification of VBEs. The following three main sub-areas are addressed for VBEs [43]:

- **Generic VBE models and mechanisms.** This sub-area has focused on conceptualisation and modelling of VBE structure and operation principles and specifically the VBE stakeholders and their roles; VBE typology; working and sharing principles; common ontologies; members profiling; competency management; value system definition; establishing basic trust among VBE members and managing the trustworthiness, among others.

- **VBE management system.** This sub-area focused on development of mechanisms and tools to support the VBE during its entire life cycle stages. These prototypically implemented tools and subsystems included: competency collection and management; trust establishment and management; VBE members management; management of VBE Bag of Assets; management the VO configuration information, management of VBE ontology; decision support in VBEs; and VBE instantiation to different application domains.

- **VO creation framework.** This sub-area has focused on supporting the creation of VOs within the VBE. It specifically addresses: guidelines for configuration and launching of VO; identification of collaboration opportunities; brokerage and planning of VOs; mechanisms for search and selection of partners based on their profiles, competencies, trustworthiness and past performance; agreement negotiation and contract establishment support.

![Figure 1.11 - The main components of ECOLEAD](image)

This Figure illustrates the main areas of the ECOLEAD project, namely the three “vertical areas” of: (1) Virtual Organisations Breeding Environments, (2) Dynamic Virtual Organisation management and (3) Professional Virtual Communities, and the two “horizontal areas” of: (4) the theoretical foundation for collaborative networks and (5) the ICT infrastructure.

(2) Dynamic VO Management. This area of ECOLEAD is aimed at development of models to support VO management. Namely the models help the VO with its planning, control, organisation and management, taking into account the of social mechanisms in multi-interest collaboration networks. The following subareas are addressed for VO management:

- **VO performance measurement approach and assessment mechanisms.** This sub-area focused on: common understanding of intra-VO shared benefits and costs (i.e. values), as well as VO performance metrics and related measurement systems.

- **VO management, coordination and supervision.** This sub-area focused on supervision, as well as comprehensive modelling of the VO processes. Specific issues include: distributed business processes (DBP) modelling methodologies and tools; models and control methods.
for adaptive and pro-active management; VO supervision including enactment, monitoring, diagnosis and error recovery; and identification, prevention and handling of conflicts in VOs.

- **VO inheritance management.** This sub-area focused on the generated knowledge, which shall be inherited after the dissolution of a VO, as well as the liabilities that need to be transferred.

**3) Professional Virtual Communities.** This focus area of ECOLEAD is aimed at leveraging human centred management and exploitation of the individuals’ knowledge for value creation within Professional Virtual Communities (PVCs). The following sub-areas were addressed for PVCs:

- **Collaboration models and social forms.** This sub-area focused on a conceptual framework for Professional Virtual Communities, addressing: identification of the open legal and social issues for PVCs; dynamic knowledge aggregation; intellectual property issues; and relationships with VOs and VBEs.

- **Advanced collaboration space platform.** This sub-area focused on specification and development of: generic collaborative support services (e-collaboration spaces), including multi-modal interfaces; with a specific emphasis on social, business and knowledge capital evaluations.

**4) Theoretical Foundation.** This focus area of ECOLEAD is aimed at the establishment of Collaborative Networks (CNs) as a recognised scientific discipline. The following four sub-areas are addressed:

- **Formal modelling foundation.** This sub-area collects a number of theories, approaches and models developed in different disciplines, and assesses them regarding their applicability to the CN modelling needs. Specific approaches addressed within this sub-area include: formal languages, graph theory, multi-agent models, game theory, and modal logics, among others.

- **Reference models for collaborative networks.** This sub-area focused on development of a comprehensive reference modelling framework and a set of reference models for the VO Breeding Environment, Virtual Organisation, and Professional Virtual Community.

- **Soft models for collaborative organisations.** This sub-area focused on the soft modelling needs in collaborative networks and elaborates on potential modelling approaches, including: causal models; soft reasoning models and decision-making support.

- **Basis for combination of models.** This sub-area focused on interoperability among different modelling tools and approaches, required for modelling CNs, and specifically on characterisation of multi-level modelling perspectives, and devising approaches for model combination and integration, in order to enrich the reference models for CNs.

**5) ICT Infrastructure challenges for collaboration.** This focus area of ECOLEAD is aimed at development of transparent, easy to use and affordable infrastructure to support the networked organisations. The following three sub-areas are addressed:

- **Infrastructure reference architecture principles for networked organisations.** This sub-area focused on platform and technology independent ICT reference architecture for collaborative networks and addressing: Software-as-Service and Interoperability Service Utility paradigms; on-demand and pay-per-use services via the concept of Services Federation; and approaches for enterprise applications integration, both at inter- and intra-enterprise level.

- **Generic security framework.** This sub-area focused on configurable, multi-level security architecture and AAA (authentication, authorisation and accounting) mechanisms; and dynamic security for allocation and revoking of access rights.

- **Transparent inter-enterprise plug-and-play infrastructure.** This sub-area focused on concepts and technologies needed to configure applications and infrastructures for networked organisations as well as an extended collaboration model where services of different CN members can be shared. Specific contributions include: elaboration of inter-enterprise plug-&-play concept in line with current infrastructure trends; federated information and resource
management support; and support for legacy systems and corporate database integration.

**Relation of ECOLEAD project to the research in this thesis.** The ECOLEAD project has involved more than twenty partners from Europe and Latin America, including (a) universities, (b) commercial companies and (c) running collaborative networks of organisations and people. The type (c) of partners, namely the collaborative networks of organisations and people, played the special role of end-users in this project, and thus actively contributed to the definition of the project’s motivations, definition and analysis of requirements, and the testing, trial and validation of all project results.

In relation to the VBEs research in the ECOLEAD project, the main input and requirements were primarily based on the empirical study of many existing networks of organisations in different countries in Europe and Latin America, the so-called “1st generation VBEs”. These large VBEs included the VIRFERBRAS from Brazil [37], Virtuelle Fabric from Switzerland [44], CeBeNetwork from Germany [45] and HELICE from Spain [46], among others. In particular, the requirement engineering stage of our work is conducted with these networks. We have studied and identified the main structural elements, life cycle stages, functionalities, as well as the main challenges, needs and other requirements of these VBE networks as the basis designing and specification of the advanced type of VBEs, the so-called “2nd generation VBE”.

The nature of the research results presented in the thesis: the conceptual work, the engineering work and the experimental work. The conceptual results represent the design of the VBE-ontology, specification of the ODMS, introduction of new models for organization competency, and specification of the PCMS system. The engineering results include the development of the VBE-ontology, prototypical implementation of the ODMS, development of the profile and competency models as a part of the ontologies, and the prototypical implementation of the PCMS. The experimental results represent our take-up activities for lunching and using the ODMS and PCMS within the environments of a number of running 1st generation VBEs, e.g. Swill Microtech.

**Research publications.** Many sections presented in this thesis have been published in a number scientific journals and peer-reviewed conference proceedings, as well as appearing as book chapters and technical reports. A summary of these publications is shown in Table 1.2, while the complete references to these publications are provided in annex G. In the left column of Table 1.2, the four components of the ColOnto system are listed, then for every component a number of publications are shown on the right. The double star sign means that a corresponding ColOnto component is addressed at least in one publication. The double star sign means addressing a corresponding component in at least two publications.

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1.7. Thesis structure

This thesis includes five main chapters and eight annexes. A brief description of these chapters and annexes follows:

Chapter 1 presents the problem area, motivation, open questions and the methodology for the research addressed in the thesis. This Chapter starts with the definition of the Virtual organisation Breeding Environment (VBE). It addresses its reference model, with the emphasis on the endogenous elements of VBE environments (namely: the VBE structure, its functionalities, behavioural polices and regulations and its resource components), as well as a number of VBEs’ distinguished characteristics, which make the creation and operation of VBE environments challenging. Specifically, it introduces four main challenges for creation and operation of VBEs. It then describes the need for development and management of ontologies for VBEs, which shall be developed to address these four challenges of VBEs, and briefly describes the methodology for their development.

Chapter 2 addresses three main issues: (1) survey of the related work, (2) case study of 1st generation VBEs and (3) analysis of VBE stakeholders’ requirements. These three issues represent the main input for development of the ColOnto system.

Chapter 3 presents development of the conceptual part of the ColOnto system, namely the definition, design and specification of the VBE8ontology. Moreover, it specifies the part of this ontology which is devoted to modelling the VBE related profiles and competencies in more detail. This Chapter addresses the research questions RQ1 and RQ2.

Chapter 4 addresses the development of the functional part of the ColOnto system, namely the specification and prototyping of the two information management systems. These Ontology Discovery and Management System (ODMS), which is developed for discovery, maintenance and management of the VBE-ontology, and the Profile and Competency Management System (PCMS), which is developed for management of profiles and competencies in VBEs. It further shows how the VBE-ontology supports information management in VBEs. This Chapter addresses the last research question RQ3, and together with Chapter 3, they also address the general research question GRQ.

Chapter 5 addresses the validation of the developed ColOnto system, summarises the research results addressed in chapters 2 to 4 and introduces other potential applications for our achieved research results as well as the future challenges.

Furthermore, the thesis has the following eight annexes: Annex A provides the list of 1st generation VBEs which participated in this research. Annex B describes a number of state of the art models and systems related to ColOnto. Annex C gives examples of questionnaires primarily used for collection of information about the current state of the art practices in 1st generation VBEs, as well as for collection of requirements for the ColOnto. Annex D provides examples from the core level of the specified VBE-ontology. Annex E provides examples from domain level of the VBE-ontology. Annex F provides examples of one specific profile and one specific competency description. Annex G gives a list of authors’ publications, addressing the topics presented in this thesis.

1.8. Conclusions

This Chapter introduces the research problem which is addressed in the thesis. It starts with presenting the background concepts of Virtual organisations Breeding Environments (VBEs). It then addresses the reasons behind the planned research, outlining a number of VBE challenges that need to be addressed by research and development. Next it presents the ColOnto (Collaborative Ontology) approach addressing development and application of ontologies for VBEs, in order to respond to the identified challenges. Based on the research problem, a number of research questions, which are addressed later in the thesis, are defined.
Then, the objectives and contributions of this thesis are addressed. The Chapter also presents the research approach and methodology followed in the thesis. Lastly, this Chapter addresses the research context of the ECOLEAD project, summarises the author’s related publications and the structure of the thesis.

This Chapter is interrelated with the other chapters of this thesis, as follows. The description of the background concepts addressed in Section 1.2 is further explored in this thesis in Chapter 2. The four identified VBE challenges (Section 1.3), as well as their projecting to information modelling and management (Section 1.2.2.2) are further addressed in chapters 3 and 4, defining the conceptual and functional solutions developed within the ColOnto system. The research methodology (Section 1.4) is further described in chapters 2 to 5, addressing the following steps: (i) identification and study of related works (in Chapter 2), (ii) analysis of generic requirements and end-users’ requirements (in Chapter 2), (iii) definition, design and specification of the VBE-ontology (in Chapter 3), (iv) development and prototyping of the VBE-ontology based management approaches (in Chapter 4) and (v) validation of the research and development results (in Chapter 5).
Chapter 2

Related work and requirements analysis

This Chapter addresses the main input for development of the ColOnto system (as introduced in Chapter 1): related work, the state of the art in practice of existing VBEs, and the VBE general as well as stakeholders’ requirements.

The Chapter starts by introducing the previous work related to ColOnto. These include the work done on defining, designing and developing ontologies, and then from another angle, it looks at the work on the conceptualisation and reference modelling of VBEs. Studying these bodies of work helps us to define and specify the VBE-ontology. The Chapter then addresses the related research on maintenance and management of ontologies, which further supports development of the Ontology Discovery and Management System (ODMS) on top of the VBE-ontology. The related research and practice is presented concerning modelling the profiles and competencies in organizations. This supports the detailed design and development of a part of VBE-ontology’s part related to profiles and competencies of VBE members. It further leads to the specification of the Profile and Competency Management System (PCMS) supported by the VBE-ontology.

This Chapter also addresses the analysis results of the state of the art in practices of running VBEs. Here, mainly the modelling and management of profiles and competencies were investigated, since ontologies are not yet effectively addressed in the running VBEs.

Lastly, this Chapter addresses the requirements identified and analysed for development of the ColOnto system. The requirement list represents both the stakeholders’ requirements collected from different VBEs, as well as some general requirements.

Results presented in this Chapter are included in author’s earlier publications, including [26][47][48][49][50].

2.1. Introduction

Prior to starting the modelling and development of the VBE-ontology within the ColOnto system, we identified and studied examples of some existing ontologies that have relevance to the VBE-ontology. The VBE information domain was then studied for its ontological conceptualisation. Especially, the area of profile and competency information was studied in detail in relation to existing 1st generation VBEs. Lastly, the expectations and requirements set by the variety of VBE stakeholders and experts were collected to be further addressed in both the building up and management of the VBE-ontology.

This Chapter specifically aims to investigate both the past and current research and development related to ontology design and management, and the VBE information conceptualisation, to position our research on VBE-ontology among the related state-of-the-art works, and to collect requirements from VBE stakeholders. In Section 2.2 of this Chapter a survey of the related work addressed in literature is presented and our research is positioned within it. In Section 2.3, the study on the state of the art in practice of existing VBEs is presented. In Section 2.4, the collected requirements are presented and analysed. Finally, Section 2.5 outlines the conclusions of this chapter.
<table>
<thead>
<tr>
<th>Related research sub-area</th>
<th>Summary of addressed elements</th>
<th>Relevance to our research</th>
<th>Addressing sections of this chapter and annex B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research area 1: Ontology engineering</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ontology engineering methodology [51]</td>
<td>- Steps for engineering an ontology from scratch</td>
<td>- Developing a methodology for engineering the VBE-ontology</td>
<td>2.2.1</td>
</tr>
<tr>
<td></td>
<td>- Relation of ontology with data, information, and knowledge</td>
<td>- Making decision on what the VBE-ontology includes in relation to VBE’s data, information, and knowledge</td>
<td>B.1.1</td>
</tr>
<tr>
<td></td>
<td>- A summary of ontology engineering purposes</td>
<td>- Confirmation of using the VBE-ontology for solving VBE challenges</td>
<td></td>
</tr>
<tr>
<td>Degree of ontology formality</td>
<td>- Two degrees introduced for formality of ontologies</td>
<td>- Making decision on formality of the VBE-ontology</td>
<td>B.1.2</td>
</tr>
<tr>
<td>Scope and content of the ontology</td>
<td>- Different types of ontologies depending on the content of the environment</td>
<td>- Definition of the content type of the VBE-ontology</td>
<td>B.1.3</td>
</tr>
<tr>
<td>Ontology building approach</td>
<td>- Different approaches for design and building up of ontologies</td>
<td>- Development of an approach for construction of the VBE-ontology</td>
<td>B.1.4</td>
</tr>
<tr>
<td><strong>Research area 2: VBE conceptualisation and modelling</strong></td>
<td></td>
<td></td>
<td>2.2.2, B.2, and B.7</td>
</tr>
<tr>
<td>Related ontologies</td>
<td>- Approaches for designing large enterprise ontologies Detailed specifying concepts from activity domains within emerging partial VBE ontologies</td>
<td>- Designing the VBE-ontology - Populating the VBE-ontology with domain specific concepts</td>
<td>2.2.2.1 and B.2</td>
</tr>
<tr>
<td>ARCON reference models for VBEs</td>
<td>- Approaches for designing a large variety of characteristics, elements, components, and aspects of VBEs</td>
<td>- Showing comprehensiveness of the VBE-ontology</td>
<td>2.2.2.2 and B.7</td>
</tr>
<tr>
<td><strong>Research area 3: Ontology maintenance and management</strong></td>
<td></td>
<td></td>
<td>2.2.3 and B.5</td>
</tr>
<tr>
<td>Ontology library</td>
<td>- Approach for grouping and re-organising ontologies for further re-use, integration, maintenance, mapping, and versioning</td>
<td>- Organising of a set of partitions within the unified VBE-ontology</td>
<td>B.5.1</td>
</tr>
<tr>
<td>Ontology engineering environments</td>
<td>- Tools for building up and viewing ontologies</td>
<td>- Creation, editing, and viewing VBE-ontology</td>
<td>B.5.2</td>
</tr>
<tr>
<td>Information discovery and ontology discovery</td>
<td>Approaches for: - Ontology-based discovery of information from text-</td>
<td>- Semi-automated ontology-based discovery of information needed for</td>
<td>B.5.3</td>
</tr>
<tr>
<td>Related research sub-area</td>
<td>Summary of addressed elements</td>
<td>Relevance to our research</td>
<td>Addressing sections of this chapter and annex B</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------------------------------</td>
<td>---------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>corpora</td>
<td>Discovery of new concepts for an ontology from text-corpora</td>
<td>VBE management sub-systems from text-corpora, - Semi-automated extension of the VBE-ontology</td>
<td></td>
</tr>
<tr>
<td>Maintaining consistency between ontologies and databases</td>
<td>Approaches for: - Conversion of ontologies into database schemas - Evolution of ontologies and databases</td>
<td>- Semi-automated design of VBE databases - Evolution of the VBE-ontology</td>
<td>B.5.4</td>
</tr>
<tr>
<td><strong>Research area 4: Organizational profiles and competencies</strong></td>
<td>2.2.4, B.3, B.4, and D.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Existing profile models</strong></td>
<td>- Chamber of commerce register of companies’ profiles - EU register of organisations involved in proposal submission</td>
<td>- Identification of a variety of organisations’ characteristics and categorising them</td>
<td>2.2.4.1 and B.3</td>
</tr>
<tr>
<td><strong>Existing related competency models</strong></td>
<td>- Competency modelling in intra-organisation managerial sciences - Competency modelling in inter-organisation managerial sciences - Competency modelling in networks managerial sciences</td>
<td>- Identification of competency elements</td>
<td>2.2.4.2 and B.4</td>
</tr>
<tr>
<td><strong>Related profile management functionality</strong></td>
<td>- Basic and advanced functions for managing collection of organizations’ profiles, as well as individual profiles collections in social networks</td>
<td>- Identification of basic and advanced profile management functions</td>
<td>2.2.4.3</td>
</tr>
<tr>
<td><strong>Related competency management functionality</strong></td>
<td>- Competency management in intra-organisation managerial sciences - Competency management in inter-organisation managerial sciences - Competency management in networks managerial sciences</td>
<td>- Identification of the variety of competency management functionalities</td>
<td>2.2.4.4 and B.6</td>
</tr>
</tbody>
</table>

**2.2. Positioning among related state-of-the-art research**

In order to develop the ColOnto system beyond the state of the art, as well as to compose and position it among the past and present related research and practices, first the related literature and practice are studied. The following main areas, also illustrated in Figure 2.1, are related to our VBE work:

- Ontology engineering
- VBE conceptualisation and modelling
- Ontology maintenance and management
- Profiles and competency modelling and management

47
This Section provides the summaries and conclusions of the state of the art research works, and positions our work, while the details about each are provided in Annex B. Below Table 2.1 gives an overview of these areas considered, namely the “Ontology engineering”, “VBE conceptualisation and modelling”, “Ontology maintenance and management”, and “Organizational profiles and competencies”, and introduces their main sub-areas. For every sub-area, the table provides a brief summary, its relevance for our work, and links to the relevant sections of this chapter, as well as the sections of the Annex B in which these areas are addressed in more details.

Below we address these four related research areas in Sub-sections 2.2.1 to 2.2.4. Please note that many references to publications addressing these aspects are provided in the Annex B and not presented here in this section.

2.2.1. VBE-ontology engineering methodology

The approach we followed for development of the VBE-ontology is primarily based on the approach presented in [52] and [51]. Ucshold’s approach consists of the following main steps:

- **Step 1. Purpose:** This step defines why the ontology is “wanted”, what it will be used for, and possible mechanisms for its use. The following issues are typically addressed at this stage: identification and characterisation of the range of potential users, definition of categories of uses, i.e. communication between people, inter-operability among systems, or system engineering, identification of motivation scenarios, and producing user requirements.

- **Step 2. Formality:** This step addresses the degree of formality of the ontology mainly by its purpose. Namely, if the ontology is aimed to support the automation of tasks, the degree of its formality increases. In some cases both formal and informal ontology is required.

- **Step 3. Scope / Subject matter:** In this step, ontologies are divided into three main groups, in line with their scope: domain ontologies (they may cover one or more domains, e.g. medicine, geology, finance, etc.), problem solving ontologies, and knowledge representation ontologies (i.e. meta-ontologies). The scope is typically addressed through definition of a set of terms covering the full range of information that the ontology must
characterise. The two processes assigning the scope definition include: (a) brainstorming, which is used for producing all potentially relevant terms and phrases for the ontology, and (b) grouping, which involves loosely structuring the terms into work areas corresponding to naturally arising sub-groups, and identifying the semantic cross-references among these sub-groups.

- **Step 4. Building:** At this step different methodologies can be applied. However, if building large ontologies, it is important that all of the previous steps of the approach are followed. If building the formal ontology, the informal ontology can be built initially to serve as a source for further development of the formal ontology. For defining new terms in the ontology, the following three guidelines should be applied: (1) the generic ontology building criteria such as: clarity, consistency, coherence, extensibility, and reusability (as also addressed in Section 2.4.1.1) should be considered, (2) the “middle-out” principle instead of “bottom-up” or “top-down” is recommended, and (3) the ambiguity of terms should be solved by focusing on concepts more than on terms, and inventing certain distinguishing labels for each concept. The building step is further divided into the following three sub-steps:
  - **Capture:** This step includes: (i) identification of key-concepts and relationships in the domain of interest, (ii) production of precise unambiguous text definitions for such concepts and relationships, and (iii) identification of terms to refer to such concepts and relationships.
  - **Coding:** This step includes the explicit representation of the conceptualisation captured in the previous step. Namely, it addresses: (a) commitment to the basic terms that will be used to specify the ontology (i.e. meta-ontology), (b) choosing the representation language, and (c) writing the code.
  - **Integrating existing ontologies:** This step addresses using either existing ontologies or some parts of them within the newly built ontologies.

- **Step 5. Evaluation / Revision cycle:** A number of existing evaluation criteria can be applied in this step. These include the generic ontology building criteria mentioned above. Other general criteria, including: (1) the domains and ranges of all defined functions must themselves be defined, (2) redundancies should be avoided, some implicit ones can be recognised. The specific criteria mainly include checking the ontology against the identified purposes and user requirements.

- **Step 6. Documentation:** For some ontologies it may be desirable to establish guidelines for documenting ontologies, possibly differing according to the type and purpose of the ontology. Documentation increases the effectiveness of ontology sharing.

In relation to the above steps for ontology engineering, a summary of the other state of the art research findings is also provided below,. More details about these studies are addressed in Annex B, Section B.1. The main **conclusions** drawn about this related works studied, and the **positioning** of the VBE-ontology among them, are outlined below:

**1. VBE-ontology - definition and purpose.** The VBE-ontology, defined in this thesis, is a conceptual representation of three facets – the VBE-related knowledge, the VBE information, and the VBE data. Specifically, VBE ontology represents certain VBE knowledge in relation to its human users who understand the meaning of these concepts. But for the software which processes this ontology, the VBE-ontology represents the data and information collected in VBEs. The main purposes for developing the VBE-ontology are consistent with the general ontology purposes addressed before, when considering that the “domain” is the “domain of VBEs”. The VBE-ontology therefore aims to support VBEs and their stakeholders and systems with the following services:
• Creating and sharing common understanding about VBE-related knowledge among both people and software
• Enabling the sharing and reuse of the VBE-related knowledge between different VBEs
• Clearly specifying the definition of the VBE-related concepts
• Separating the general VBE-related knowledge (e.g. about VBE structure, and VBE’s general activities) from the knowledge about VBE’s domains/areas of activities (e.g. metalworking, healthcare, tourism)
• Processing and analyzing of the VBE-related knowledge

2. VBE-ontology - formality. In relation to the formality of the VBE-ontology, for our purposes, the specified VBE-ontology is more lightweight, since it does not aim to support axioms. However, it has some of the features of heavyweight ontologies, since it is formal enough to support its processing through software. It also follows the main principles for building heavyweight ontologies, as introduced in [23].

3. VBE-ontology - structure and content. For our purposes, the VBE-ontology represents a combination of a core ontology and a domain ontology. The VBE-ontology addresses the following two main domains/contexts. The first domain is the general VBE domain addressing common characteristics of VBEs (e.g. VBE structure and roles of the VBE actors). The second domain is the domain/area of activities of the VBE member organisations, and thus the focus area of the entire VBE (e.g. metalworking, healthcare, tourism). The first domain also represents the root for the second domain. For example, the VBE “competency” concepts from the first domain can be populated with the “milling” concept within the second domain.

4. VBE-ontology - building approaches. A combination of a number of building approaches shall be used at different stages of specification and prototypical engineering of the VBE-ontology [53]. For example, the design/ general structure of our entire VBE-ontology shall be developed using the Inspiration approach. Furthermore, the base classification of concepts shall be suggested through the analysis of a set of specific VBE applications, thus the Deduction approach shall be used. Similarly, different ontology engineering approaches shall be integrated into the methodology for engineering the VBE-ontology. Namely, some parts of the VBE-ontology shall be developed manually by the experts. Other parts shall be developed using the existing structured and unstructured ontology resources, as well as through integration of existing ontologies. In relation to the language for ontology engineering, for our purposes, the VBE-ontology shall be OWL-based, since OWL provides better means for development of more formal ontologies.

2.2.2. VBE conceptualisation and modelling

This Section first positions our work among the relevant existing ontologies, related to the field of collaborative networks, including the emerging partial ontologies developed for VBEs. Second, it addresses the relevance of our work to the ARCON’s reference model for VBEs, which is briefly introduced earlier in Section 1.2.2.

2.2.2.1. Related ontologies

Two types of ontologies developed in past research are related to our research. This Section briefly addresses the position of our VBE-ontology among them, while Annex B.2 described these related ontologies in more details.

The first type of related ontologies represents the enterprise ontologies (see Annex B.2.1 for more details). These ontologies typically focus only on the internal structure and processes of the enterprise. Thus, they do not address networks of enterprises, and particularly VBEs. However, these ontologies have one advantage, which is the fact that they
are mature. Namely, the approaches and methodologies developed for their design and specification have passed the test of time. Therefore, to the extent possible these approaches and their methodologies are considered for the design and specification of the VBE-ontology.

The idea of the decomposing of the large ontology for the sake of its reusability and digestibility, as used in the enterprise ontologies, is beneficial and applied to the VBE-ontology. Considering that the VBE itself is also an enterprise, some concepts from the enterprise ontologies (e.g. “Product” and “Customer”) are also applied to the VBE-ontology. However, most other concepts from the enterprise ontologies are too generic (e.g. “Doer” and “Event”) and do not specifically apply to VBEs.

The second type of ontologies represents a few ontologies developed to partially address some aspects of the VBEs (see Annex B.2.2 for more details). These recently developed ontologies are also considered related to building our unified generic VBE-ontology. Since these ontologies address only some specific aspects of the VBEs, their related parts are integrated into the design of the unified generic VBE-ontology.

2.2.2.2. ARCON reference models

The ARCON reference model for VBEs (see Annex B.7 for more details) is considered as the most relevant to our research, and specifically the conceptualisation method used in ARCON is examined for application in design and development the VBE-ontology. At present, ARCON represents the only comprehensive model of VBEs approved within the academic and research community, therefore the VBE-ontology is closely interrelated with it. The following summarises the specific interrelations between our proposed VBE-ontology and the ARCON:

- **Applying ARCON subspaces.** The Endogenous subspace of the ARCON reference model is applied to building the VBE-ontology and not its Exogenous subspace, since the first one addresses the information management activities as a part of the VBE operation stage.
- **Applying ARCON dimensions.** The Structural dimension, the Componental dimension, and the Behavioural dimension of the Endogenous subspace refer to their related VBE information types which are specified by the VBE-ontology. The Functional dimension of the Endogenous subspace refers to the systems/tools through which the VBE information is managed. However, their information types needed by these tools is also addressed by the VBE-ontology.

2.2.3. Relevant ontology maintenance and management functionalities

The state of art research on ontology maintenance and management (see Annex B.5 for more details), is considered in order to: (a) address the variety of useful functionalities that our ODMS system can provide, as well as (b) to position these functionalities among other functionalities presented in the research literature.

As a result, the following main set of processes/operations on ontologies are identified as the most relevant, and developed within the ODMS system:

- ontology registry management,
- ontology editing,
- ontology navigation,
- ontology integration,
- ontology evolution,
- ontology-based knowledge discovery,
- ontology concept discovery, and
- ontology-based repository design and maintenance.
2.2.4. Relevant models and functionalities for organisational profiles and competencies

This Section briefly introduces a summary of the state of art research and practice in relation to organisations’ profiles and competencies and positions our developed profile and competency management among them.

A main objective for the state of the art investigation was to identify the structure of existing organisations’ profiles and competencies, as well as some of their related issues, e.g. including the objective for collection of profiles and competencies, the data confidentiality issue, and similar aspects that influence modelling of the generic unified models of profile and competencies for VBEs. Moreover, in order to specify and develop the PCMS’s functionality, the state of art research on profile and competency management is considered, and addressed in this section. Below we first address the research on modelling and then on the management of the profile and competency in the next four Sub-sections.

2.2.4.1. Profile modelling

There is no generic and uniform definition for organizations profiles, as needed in VBEs. Through the Web typically links are provided to pages/documents with different formats and contents presenting individual companies’ profiles, which are published mainly for the sake of promoting companies to potential clients and customers. However, only a few existing uniform collections of organisations’ profiles, similar to what is needed in VBEs, have been identified. This Section briefly describes two such example collections of organisations’ profiles that were compiled for reasons other than supporting a network of organizations. More details about these profile collections are addressed in Annex B.3.

These collections are considered in order to identify generic or common categories of characteristics among organisations, that can be reused for design of the ontology for VBE members’ profiles. The first collection is at the governmental-level (Dutch) and represents the profile register of the Dutch Chamber of Commerce. The second collection is at the European-level and represents the profile register of the EU proposal submissions.

The structure of the organisation’s profile within these two considered examples is different, since the profiles of the two systems are designed and used for different purposes. For example, the profiles of the Chamber of Commerce are used for analysis of the economic situation in the country; while the profiles of the EU register are used for selection of the best organisations to accept their proposals. Clearly, the profile structure for the VBE member organisations cannot duplicate any of these two profiles structures; instead, some generic or common elements from these profiles are identified to be reused. The main observations and conclusions relevant to our research are presented below in Table 2.2.

The main relevant aspects extracted from the state of the art and applied to specification of the VBE members’ profiles follow:

- The organisations’ profile structure directly depends on the purpose of the profile information.
- Profile representation typically forms an embedded list and not a flat list, which is effective and crucial in case of large amount/variety of profile characteristics.
- The organizations’ profiles include generic characteristics, such as contact data, size of organisation, financial data, etc. and specific or detailed, e.g. main markets, independence, and affiliation. Also, distinction between mandatory profile characteristics and the optional ones is important.
Table 2.2: Summary of related work on organisations’ profiles

<table>
<thead>
<tr>
<th>Example existing profile collections</th>
<th>Objectives for collecting profiles</th>
<th>Structure of profiles</th>
</tr>
</thead>
</table>
| Commercial organisations within the Dutch Chamber of Commerce (see D.3.1 for more details) | - Market or academic research  
- Analysis of the economic situation in the country  
- Undertaking of a specialised campaign aimed at a particular target group | - Several embedded information categories  
- Variety of collected information types: contact data, legal forms, financial data, roles and functions within a company, summary of Figures  
- No competency description is addressed in profiles |
| Non-commercial organisations within the EU register of project proposals(see D.3.2 for more details) | - Selection of the best organisations to accept their proposals                                                               | - A flat list of information categories  
- Variety of collected information types: name, contact data, legal status, financial data, independence, affiliation  
- Addressing some competency information, namely the activity type according to NACE classification |

2.2.4.2. Competency modelling

There is also a lack of relevant competency models in the collaborative networks domain. Because of this, our research on VBE competency model for organizations is positioned well among the state of the art competency models addressed in literature by different scientific disciplines. Table 2.3 presents a summary of the state of the art competency models. It specifically addresses their main objectives, competency definitions, fundamental competency components, and their application areas. The detail of these models are addressed in the annex B.4, but the conclusions of this study are outlined below in this Section while addressing the main research results.

The summary of the main relevant aspects extracted from the state of the art, and applied to VBE members’ competencies follow:

1. The specificities of VBE members’ competency definition and competency model directly depends on the purpose. For example, the s-a-r-C model serves competency matching against specified tasks or individual competency increase, but it does not serve for planning of production systems.

2. There are two components of competency that are common to all models, and also exist in the VBE competency model, namely (i) “resource”, including “human resource” (also-called “actor”), “physical resources”, “ICT resources” (also referred to as “technologies” or “skills”), etc., and (ii) “activity” (also referred to as “process”, “production skill”, “capability”, “professional situation”, “task” or “problem”). The absence of uniformity in naming the same competency components does not play a big role and is caused by different contexts where the competency in question is being modelled.

3. The studied competency models provide different extensions to the two base constituents addressed above in point 2, for example “competency classification”, “competency weight”, or “competency evidence”.

4. The structure and level of details addressed in competency models depend on further intentions of using this specific model. Models, which are used for further creation of competency repositories, and structuring and processing of competencies, such as in the HR-XML model, are specified in more detail.

53
### Table 2.3: Summary of related work on organizations’ competency models

<table>
<thead>
<tr>
<th>Example existing competency model</th>
<th>Objective for collecting competencies</th>
<th>Definition and/or structure of competency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>As addressed in intra-organisation managerial sciences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core competence notion (see D.4.1.1 for more details)</td>
<td>Strategic planning and providing means for achieving better synergies among the various business units in a multi-business corporation.</td>
<td>– Definition: “the collective learning in the organisation, especially how to co-ordinate diverse production skills and integrate multiple streams of technologies” [54]</td>
</tr>
</tbody>
</table>
| Core competence hierarchy (see D.4.1.2 for more details) | Extension of the core competency notion. | Structure [55]:  
  – Resources (physical resources, human resource, organisational resources)  
  – Capabilities (organisation abilities to exploit resources)  
  – Competencies (cross-functional integration and coordination of capabilities)  
  – Core competencies (skills and areas of knowledge that are shared across business units and result from integration and harmonisation of business units’ competencies) |
| **As addressed in inter-organisation managerial sciences** |
| **HR-XML competencies schema (see D.4.21 for more details)** | Providing trading partners standardised and practical means to exchange information about competencies within a variety of business contexts | Definition [56]: “a specific, identifiable, definable, and measurable knowledge, skill, ability and/or other deployment-related characteristic (e.g. attitude, behaviour, physical ability) which a human resource may possess and which is necessary for, or material to, the performance of an activity within a specific business context”  
  Structure:  
  – Taxonomy Id  
  – Competency Id  
  – Competency Evidence  
  – Competency Weight  
  – Competency (resulted from the decomposition the “top-level” competency) |
| **As addressed in networks managerial sciences** |
| Core Competencies in the manufacturing clusters (see D.4.3.1 for more details) | Matching completion of the tasks defined for a new VO with the constituent skills provided by the cluster of organisations | Structure [33]:  
  – Products  
  – Processes (Business Processes)  
  – Skills (Technology)  
  – Task (set of activities/operations) service |
<table>
<thead>
<tr>
<th>Example existing competency model</th>
<th>Objective for collecting competencies</th>
<th>Definition and/or structure of competency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competence cells (see D.4.3.2 for more details)</td>
<td>Planning of production system in the competence cell-based networks</td>
<td>Definition [57][58]: “the smallest autonomous performance unit able to create value, be indivisible and able to exist independently” Structure: – Competence of humans – Resources (production areas, stocks, personnel, work equipment and auxiliary equipment, organisational and financial means) – Fulfilled task or executed function</td>
</tr>
<tr>
<td>s-a-r-C model (see D.4.3.3 for more details)</td>
<td>Competence increase for individual firms within a network of firms</td>
<td>Definition [34][35]: “the interaction between three components: the professional situations, the actors, and the resources” Structure: – Professional Situation (tasks and problems) – Actor (human resources of the firm) – Resource (material capabilities)</td>
</tr>
</tbody>
</table>

**2.2.4.3. Profile management**

Not much research addresses generic principles of organisation’s profile management. There are however, specific practices of profile management for organisations and people. In relation to existing practices for organisations’ profile management, we have ascertained that most of them are performed only through simple GUIs for the organisations’ information databases, with the basic functions of submission and retrieval of organisation’s data, and lack advanced functionalities for the organisation’s data management, e.g. supporting semi-automated processing of profiles. Also, while individual organisation’s / company’s profiles exist and are managed, classification and management of collective profiles is not addressed. For the organisations’ profiles addressed in Section 2.2.4.1 (namely, the register of the Dutch Chamber of Commerce, and the profile register of the EU proposal submissions) no online management functionalities are introduced to be accessible by general public.

In this Section we only address the management of groups of people’s (individuals’) profiles that can be applicable to the PCMS development. The groups of people’s profiles are addressed in relation to social networks (e.g. “FaceBook” [59] and LiveJournal [60]). The profile management in Social Networks is interesting and useful for VBEs, as addressed further in this section.

Given that the Social Networks are popular nowadays, their profile management functions are continuously extended and improved and some of the specific and interesting functions introduced for people’s profiles can be reused for organisations’ profiles. However most functions in such systems still represent simple GUI functions for database manipulation, such as data submission through forms, data displaying and data search. A few more advanced functions are also identified that can be also useful for the networks of organisations as well. Examples of such functions include:

- Identification of common parts among the individuals’ profiles
- Identification of common interests of individuals
- Clustering of individuals by different characteristics (e.g. interests, location, etc.)

The above more advanced functionalities for profile management are also of interest for VBEs. For example, the member organisations and VO brokers benefit from constant clustering of organisations, i.e. identification of groups of organisations that have some
similarities, e.g. being similar in visions/missions, locations, machinery resources, etc.. Below Table 2.4 addresses the summary of our findings on profile management, applied to PCMS.

Table 2.4: Summary of considered functionalities related to an organisation’s profile management

<table>
<thead>
<tr>
<th>Functionalities for profile management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic functions</strong></td>
</tr>
<tr>
<td>• Collecting profile data</td>
</tr>
<tr>
<td>• Communicating profile data</td>
</tr>
<tr>
<td>• Displaying of profile data</td>
</tr>
<tr>
<td>• Search for profile data</td>
</tr>
<tr>
<td><strong>Advanced functions</strong></td>
</tr>
<tr>
<td>• Identification of common parts in the individuals’ profiles</td>
</tr>
<tr>
<td>• Identification of common interests of individuals</td>
</tr>
<tr>
<td>• Clustering of individuals by specific characteristics (e.g. interests, location, etc.)</td>
</tr>
</tbody>
</table>

2.2.4.4. Competency management

Research related to organisation’s competency management is addressed in relation to the intra-organisational, inter-organisational, and network managerial sciences. But the reported results mainly specify the needs, requirements, and/or some early specifications of required competency management functions. No comprehensive approaches or prototyped mechanisms are so far reported for management of competencies in networks, such as the VBEs.

Table 2.5: Summary of identified state of the art functionalities for organisation’s competency management

<table>
<thead>
<tr>
<th>Functionalities for competency management addressed in intra-organisation sciences (see D.6.1 for more details)</th>
<th>Functionalities for competency management addressed in inter-organisation sciences (see D.6.2 for more details) and network managerial science (see D.6.3 for more details)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Competency definition: Identification of both acquired and required human competency, Definition of strategic competency</td>
<td></td>
</tr>
<tr>
<td>• Competency assessment: Assessments of competency levels, Performance measurement that measures competencies</td>
<td></td>
</tr>
<tr>
<td>• Competency acquisition: Recruiting human resources, Specification of training curricula and individual courses that build competencies within an organisation, Core-competency development, Core-competency consolidation</td>
<td></td>
</tr>
<tr>
<td>• Competency structuring: Structuring of the competency catalogue, Inventories of workforce competence (taxonomies for general and specialised uses)</td>
<td></td>
</tr>
<tr>
<td>• Competency-based management: Competency-based performance measurement, monitoring &amp; reporting, Competency-based individual performance development planning and goal setting, Automated job descriptions, Competency-based career development systems, Selection procedures that assess competencies, Succession planning systems, Pay-for-competencies compensation systems</td>
<td></td>
</tr>
<tr>
<td>• Competency evaluation: Assessments of competencies, Evaluation of competencies by peers, Monitoring and evaluation of current set of core competencies</td>
<td></td>
</tr>
<tr>
<td>• Competency acquisition: Collection of member organisations’ core-competencies, Development of new core competencies in the Selection of new VBE members with the core competencies needed, Development of a Competency Management program for the VBE</td>
<td></td>
</tr>
<tr>
<td>• Competency-based management: Matching competencies against the business opportunities that arise</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.5 summarises these findings on organisation’s competency management related to three different research areas, including: intra-organisation sciences, inter-organisation research sciences, and the network managerial science, which contributed to our design to competency management functionalities for VBEs. These are further addressed in more details in Annex B.6.

2.3. State of the art in practice of VBEs

A number of successful running 1st generation VBEs are addressed in annex A. In our study, these VBEs are either directly interviewed or have provided information through the questionnaire Q-a (see annex C) which was distributed among more than ten running VBEs in Europe and Latin America. While we have concluded that these VBEs (similar to a large majority of other running VBEs) have no current practice that uses ontologies, many of these VBEs have dedicated systems for managing the profiles and competencies of their members. This Section presents our findings about the state of the art in profile and competency modelling management in the existing / running VBEs.

Through this study we have identified the structure and elements of their profiles and competencies, the confidentiality issues related to profile data, the physical representation of profiles and competencies, and their management functionalities among others.

Most VBEs store member organisations’ profiles in HTML or Excel files, created and updated manually by a VBE administrator or a VBE coach. Thus, the profile management functionalities in most VBEs are very limited. In relation to competency, in the practice of the existing VBEs, while competency management has already been identified as an important driver for VBE’s operation and evolution, it is nevertheless not yet developed as a system.

The remaining of this Section addresses the analysis of results collected in our study from the running VBEs. We briefly address in the following two Sub-section both the modelled information as well as the management of profiles and competencies.

2.3.1. Profile models

Through the interviews with VBEs as well as the questionnaire Q-a (as addressed in Annex C.1) the main observations in relation to existing VBE’s profile models are listed below:

- **Profile objectives.** The main reason for collection of members’ profiles is facilitation of partners’ search and selection process.
- **Profile representation.** Three out of five VBEs stated that they store profiles data in their VBEs in a relational database. The other two VBEs store the members’ profiles in Microsoft Word documents.
- **Profile structure.** The VBE representatives state that the profile’s structure in their VBEs is the same for all different types of members (i.e. members belonging to different activity domains types or having different roles inside the VBE). The general VBE members’ profile elements typically include: general information (name, contacts, legal status, etc.), products / services information, customers / suppliers information, business processes information, performance indicators / benchmark data, competencies, strategy and goals of a company, ICT/human/physical resources.
- **Profile data confidentiality.** Three levels of confidentiality were observed for the profiles in existing VBEs, namely (1) information available only to the VBE administrator (all information), (2) information available only to all VBE members (such as general information, including name, contact, address, and industry sector, and information about
products and services), and (3) information available to public outside the VBE, mainly
genral information.

The main conclusion we draw from the collected information on member organisations’
profiles is that depending on the level of ICT support, the profile information within
the existing VBE differs, ranging from a small list of items stored in Microsoft Word
documents to a large embedded list of items stored in a small relational database.

2.3.2. Competency models

Only some of the existing VBEs collect and manage information about their member
organisations’ competencies. The main observations in relation to existing VBE members’
competency models are listed below.

- **Objective for competencies collection.** The main objective for collection of competencies
  is to select the best-fit partners for new VOs.

- **Competency handling.** Existing VBEs often have no proper understanding and definition
  for “competency”. Therefore, only some VBEs can properly handle the competencies of
  their members.

- **Competency structure.** The VBE members’ competencies are in most cases represented
  by a combination of the member’s products / services, business processes, and resources.

The main conclusion we draw from the collected information is that most existing
VBEs have no proper definition for “competency”, and frequently do not handle
the competency information about their VBE members.

2.3.3. Profile management

The existing VBEs run a few operations for management of their profiles. Our main
observations follow:

- The storage of profile information is mostly performed in form of MS Excel files, but
  a few VBEs use relational databases.

- For viewing the profile data, some VBEs use web-based GUIs for displaying partial profile
  data of their members (but mainly for the sake of VBE advertising). The GUI is typically
  represented by static HTML pages.

- The collected profile data is intended mainly for access by the VBE administrators and
  coaches, but not for the peer VBE members access.

In fact, the faced difficulty in handling increasingly large Excel files, together with
the lack of systematic principles for enhancement of VBE profiles management were some of
the main factors that attracted successful running VBEs to get interested in participating
within the EU-funded ECOLEAD project.

The main conclusion we draw about the existing VBE’s profile management is that in
most running VBEs, there is a lack of digitised system and a database representing profile
information, and the existing functionalities for profile management are very limited. This
posed the need for introduction of advanced profile management approaches.

2.3.4. Competency management

Competency management in running VBEs is as limited as their profile management,
addressed in previous section. Most running VBEs do not handle the competencies of their
members. The few VBEs which collect organisations’ competencies do this as a combination
of information about organisations’ business processes and their resources. There is also still no specific and/or advanced functions for competency management.

The main conclusion we draw about existing VBE’s competency management is that while the role of competency management is understood by running VBEs, they still apply very limited digitisation of competencies and do not practice competency management.

### 2.4. Requirements analysis

Requirements engineering encompasses tasks that go into determining the needs or conditions to meet a new or altered solution and product, taking into account the requirements of its various stakeholders.

In this research the requirement engineering approach [61] and [62] is applied to: (1) identify requirements for the ColOnto solution, and (2) validate the solution’s components against the requirements.

- **Step 1 - Eliciting requirements:** Communicating with stakeholders (e.g. customers and users) to determine their requirements, also-called requirement gathering.
- **Step 2 - Analyzing requirements:** determining whether the stated requirements are unclear, incomplete, ambiguous, or contradictory, and then resolving these issues.
- **Step 3 - Recording requirements:** Documenting the requirements, which can be in various forms, such as natural-language text, use cases, user stories, or process specifications.

As such, the VBE related stakeholders were identified and contacted, their requirements were analyzed, and the final summary was assembled and documented.

Furthermore, also for the development of the ColOnto system, the stakeholders were involved. Namely, there were two trial sessions and one take-up session organised within the ECOLEAD project, when the stakeholders assessed and validated the ColOnto solution and could specify additional requirements. Thus, the primary validation for our solutions is based on satisfying the stakeholders’ requirements.

Further to user requirements, a number of generic requirements are also identified and considered for our design of ColOnto. These are not from the stakeholders, but represent standard requirements for ontologies and development of management software systems.

This Chapter first specifies the considered generic requirements (Section 2.4.1). It then addresses the characterisation of the stakeholders, our applied stakeholders’ requirements analysis approach, and finally the list of collected and analysed requirements (Section 2.4.2).

### 2.4.1. Generic requirements

Some general requirements are identified both for the conceptual and functional parts of the ColOnto system. These requirements represent the main standard usage of ontology engineering (Section 2.4.1.1) as well as the engineering of management software systems (Section 2.4.1.2).

#### 2.4.1.1. Generic ontology specification requirements

In [63] a set of general design criteria are defined for ontologies. These criteria are adapted for the design of the VBE-ontology:

- **Clarity:** The VBE-ontology should effectively communicate the intended meaning of its defined terms. Definitions of its terms should be objective.
- **Coherence:** The VBE-ontology should be coherent, namely the definitions must be consistent.
• **Extendibility:** The VBE-ontology should support introduction of new terms when necessary, in a way that does not necessitate the revision of the existing definitions.

• **Minimal encoding bias:** The encoding bias of the VBE-ontology should be minimised, considering that the VBE-ontology is intended to be used for a very long time, during which other ontology languages or style of representation might have been developed.

• **Minimal required ontological commitment:** The VBE-ontology should require minimal ontological commitment, sufficient to support the intended knowledge management activities. Such a commitment is required to allow the parties, committed to the ontology, the freedom to specialise and instantiate the VBE-ontology as needed. The ontological commitment shall be minimised by defining only the terms that are essential to the communication of knowledge.

### 2.4.1.2. Generic requirements for ontology management software system

General characteristics that affect software quality is presented in [64]. These characteristics are the base for ISO 9126-1, the international standard for evaluation of software quality. McCall’s characteristics are grouped into three groups, namely the operational characteristics, the product transition characteristics, and the product revision characteristics as shown in Figure 2.2.

These general characteristics are to be applied as the requirements for design of the ODMS and PCMS. However, since our research objectives include implementation of the software prototype for the ODMS and PCMS and not developing a software product, those characteristics related to product transition and product revision, as well as the two operational characteristics of integrity and interoperability are not applied. Therefore, only the following operational characteristics are addressed for validation of the ODMS and PCMS as the most relevant, namely:

• **Correctness:** the extent to which a system satisfies its specifications, and fulfils the customer’s mission objectives

• **Reliability:** the extent to which a system is expected to perform its intended function with the required precision

• **Usability:** the amount of effort required to learn, operate, prepare input, and interpret output of a system

• **Efficiency:** the amount of computing resources and program code required by the system to perform its function

![McCall’s software quality factors](source: [64])

*This Figure illustrates the three groups of McCall’s software quality factors, namely the operational characteristics, the product transition characteristics, and the product revision characteristics. To validate the software systems developed within this research, only the operational characteristics are applied.*
2.4.2. Fulfilling stakeholders’ requirements

As mentioned earlier, the requirements’ identification is performed in collaboration both with end-users and other stakeholders from more than ten industrial VBE networks, as well as with experts in the area of Collaborative Networks and VBEs. These two main classes of participants are classified and characterised below:

1. **The industry users** from running VBEs consisted of VBE administration, VBE coaches, as well as regular VBE member organisations. Specifically, fifteen networks from Europe and Latin America were involved in the ECOLEAD project and participated in our requirement analysis stage. Eight VBE networks which provided substantial support during this research, including: IECOS from Mexico, Virtuelle Fabrik AG from Switzerland, Toolmaker Cluster of Slovenia (TCS) from Slovenia, VIRFEBRAS from Brazil, HELICE from Spain, CeBeNetwork from Germany, Automotive Cluster of Slovenia (GIZ ACS) from Slovenia, and Swiss Microtech (SMT) from Switzerland. Short descriptions of these networks are provided in annex A.

2. **The domain experts in the field**, representing the research/academic experts in the area of Collaborative Networks and VBEs. This group mainly included university professors and members of research institutes. The contacted domain experts were either involved in the ECOLEAD project, represented experts from external CNs, or were members of the international SOCOLNET society (Society of Collaborative Networks) [65]). Several of these experts, who act as the VBE coaches in their regional networks, actively participated in requirement analysis and evaluation activities carried out in our research.

Unlike the process typically implemented for identifying requirements in software development, whereby the requirements are specified by the stakeholders and then analysed and summarised by the software engineers and developers, the identification of requirements for ColOnto’s conceptual and functional development required collaboration between the author of this thesis and these stakeholders. This approach had to be adopted on the one hand because of certain peculiarities of 1st generation end-users, including: (1) Users did not have a clear idea how to express their requirements, (2) Users were technically unsophisticated”, and (3) Users were not acquainted what the current technology can provide for them. On the other hand, the stakeholders lacked the knowledge about the terminology introduced in research for 2nd generation VBEs and their management, which at the beginning of the requirement engineering process was an obstacle both for communication with the stakeholders as well as for collecting their requirements.

To identify the requirements, the stakeholders were contacted both personally and through online questionnaires. The main task for contacting the end-users was identification of current VBE needs and requirements, as well as periodic assessment and validation of the suggested solutions. At the same time, the main aim for contacting domain experts was the identification/validation of the future desirable aspects and requirements for the VBEs of the 2nd generation.

The requirements for the ColOnto solution are collected through questionnaires Q-b1 and Q-b2, addressed in annex C, that were then analysed and summarised, as addressed below. For this purpose, similar requirements were combined within one aggregate requirement.
2.4.2.1. Ontology design requirements

In relation to the design of the VBE-ontology itself, the VBE stakeholders stated the need for specifying the following three types of terminology for the VBEs:

- **Domain/business area terminology** - related to highly technological and/or mechanical manufacturing
- **New VBE related technological/scientific terminology** – as appear in the literature and the R&D projects
- **Terminology related to European and international norms and standards** - adapted from these sources for use by the VBE actors

2.4.2.2. Ontology management requirements

The stakeholders also addressed the following functionality requirements for the ODMS system:

- **Confidentiality support**: VBE representatives stated the need for partial VBE-ontology confidentiality.
- **GUI for ontology non-experts**: A main disadvantage of most existing ontology editing/viewing environments is the complexity of their user interfaces for novice users. Namely, these editors are developed to support the work of competent and experienced ontology experts and software engineers. Thus, their usage by regular VBE actors who have no expertise in ontology engineering is problematic. In order to support both the VBE’s regular members as well as domain specialists, who are not experts in ontologies, with familiarising themselves with the VBE terminology, the ODMS need to include a user-friendly, intuitive GUI to navigate the VBE-ontology.
- **Domain-independence**: The stakeholders requested that the ODMS should be easily adaptable to any specialized VBE domain of activities and any specific VBE application.
- **Concepts cataloguing**: Cataloguing ontology concepts should specifically cover the “part of” relationship to facilitate understanding of the structure of VBE-related objects, addressed as concepts in the VBE-ontology.
- **Capturing specific ontology parts**: It should be possible to have topic-based access to view the VBE-ontology, since viewing the entire large ontology is difficult to digest by human actors.
- **Support for collaborative ontology engineering and evolution**: The ontology management tool needs to support accessing the VBE-ontology by different types of users, such as VBE-administration, ontology experts, regular VBE members, domain experts, etc., who should be able to collaborate with each other in order to engineer and evolve the VBE-ontology.

2.4.2.3. Profile and competency modelling

The main conclusions of our requirement analysis related to VBE member’s profile models are listed below:

- **Profile components**: VBE profiles must include: contact information, business process, human/physical/ICT resources, products/services, best practices, and associated partner organisations, as their main elements.
- **Profile validity**: The validity of the provided profile information needs to be properly addressed in the VBE. A strict system (e.g. certificates) shall exist, with which VBE members can evaluate the validity of data provided by others, in order to assure information accuracy, and so that organisations do not claim false information or competencies at the VBE level.
The main conclusions of our requirement analysis related to VBE member’s competency models are listed below:

- **Competency components**: Organisations’ competencies are different in each VBE. The main groups of competency elements represent:
  - Tasks, business processes, jobs, core business activities, and practices, through which the organization has the ability to perform
  - Human/physical/ICT resources (e.g. the knowledge, skills, and even attitude of personnel, or the available machinery in the organisation) which the organization possesses
  - Products and/or services offered in the market/society

- **Competency availability, i.e. provided capacity**: The VBE member organisation’s profile also needs to indicate the available capacity of the member’s competency which can be offered in the VBE, also-called free capacity.

- **Competency costs**: VBE member organisations are typically interested in “selling” their competencies within the VOs. Thus, the costs of their competencies also need to be specified.

- **Applicability to all organisations**: There should be a single “competency model” representing all organisations within the VBE.

- **Domain independence**: The competency model should be able to cover features from a variety of different domains (i.e. from manufacturing to health care).

**2.4.2.4. Profile and competency management system**

VBE stakeholders have outlined the following requirements for the PCMS system:

- **Profile and competency catalogue**: According to VBE stakeholders, the profile and competency catalogues should be arranged as follows:
  - The catalogue should form a tree of data.
  - The catalogue should be flexible, i.e. there should be different options in regards to the layout of the catalogue, depending on different criteria. For example it should display either the individual competencies or the collective competencies of VBE members. It should also have a user-friendly interface.

- **Domain independence**: PCMS needs to be adaptable to different domains of activities, so that it supports the extension and evolution in the VBE domain of activities.

- **Coping with large amount of data**: Typically VBE member organisations need to submit large amounts of data. The interface for data submission in PCMS should be convenient and facilitate this process.

- **Customisation of profile and competency model**: The PCMS should support on-demand changes in the profile and competency models of the VBE.

- **Dynamic extension of competency classes in the VBE**: When new VBE competencies are needed or added, new competency classes should be specified and/or at any time added to the PCMS.

Some requirement for competency management in VBEs are further addressed in [14]. Particularly, the following functions for management of competency are identified:

- Competency appraisal
- Competency gap analysis
- Accreditation of competencies
- Development of “complex” competencies

63
2.5. Conclusion

This Chapter addresses the main input for development of the ColOnto system consisting of three parts, namely: the related state of the art in research, the related state of the art in practice of running 1st generation VBEs, and analysis of requirement for developing the constituting elements of the conceptual and functional parts of ColOnto.

The Chapter starts by addressing the related research works and positioning the conceptual and functional aspects of ColOnto among them. First, it presents the related work on defining, designing and developing ontologies, which support definition and specification of the VBE-ontology. The related research on maintaining and managing ontologies is then presented, e.g. addressing ontology integration, evolution, discovery, etc., which further supports development of the Ontology Discovery and Management System (ODMS) on top of the VBE-ontology. The research on characterisation and reference modelling of Collaborative Networks (CNs) is then addressed, which conceptualises the VBEs. The Chapter then presents both the related research and practice in modelling organisations’ profiles and competencies. These constitute the base for the design and development of the part of the VBE-ontology related to the VBE members’ profiles and competencies. It then addresses related research on the management of organisations’ profiles and competencies which constitute the base for specification of profile and competency management functionalities addressed in the Profile and Competency Management System (PCMS).

After presenting the related research work, the Chapter outlines the conclusions from our requirement engineering study in a number of running 1st generation VBEs. The modelling and management of profiles and competencies were investigated, since ontologies are not yet addressed by the running VBEs.

The Chapter also addresses the requirements identified and analysed for development of the ColOnto’s conceptual and functional solutions. These include both generic requirements and requirements collected from the VBE stakeholders.

The conceptual results of the research on the development of the VBE-ontology (Chapter 3) and the functional results of the research on management of the VBE-ontology (Chapter 4) use the materials presented in this Chapter as an input. Also, validation of the ColOnto system (Chapter 5) uses both the generic requirements and the stakeholders’ requirements addressed in this chapter.
Chapter 3

Conceptual design of ColOnto system

This Chapter introduces the conceptual aspects of the ColOnto system. The main aim for specification and development of a unified ontology for VBEs, the so-called “VBE-ontology”, includes: establishing common understanding among VBE members, supporting instantiation of VBEs in different domains, handling dynamism and scalability of VBE activity areas, and boosting and balancing the involvement of heterogeneous VBE members in potential VOs. Furthermore, the VBE-ontology offers the formal and comprehensive specification of the VBE knowledge, usable by both human actors and software components.

This Chapter introduces the methodology which we have developed and applied for construction of the VBE-ontology. It provides details about steps of this methodology, including definition of scope, design of the VBE-ontology, and identification of techniques for developing the VBE-ontology. The Chapter then narrows down and provides the in depth specification for one of ten addressed sub-ontologies of the VBE-ontology, devoted to profiles and competencies. Competencies in VBEs specifically serve the challenge of boosting and balancing involvement of the VBE members in potential VOs that are established within VBE. The Chapter presents several example screenshots from the implementation of this sub-ontology.

Parts of this Chapter have been previously addressed within some of the author’s earlier publications, including [66][26][67][48][68][69][49][70][50].

3.1. Introduction

Ontologies are increasingly applied in a wide range of areas of research and development as the means of representing knowledge about environments, e.g. in artificial intelligence, semantic web, biomedical informatics, and library science among many others. This Chapter presents an ontology which conceptually defines the Virtual Organisation Breeding Environments and aims to support the VBE operation and management stages.

As addressed earlier in Chapter 1, Section 1.2.3, the “VBE-ontology” is an instrument to support several challenges of 1st generation VBEs, especially including: (I) establishment of common understanding, (II) VBE instantiation in different domains, (III) supporting dynamism and scalability in VBEs, and (IV) boosting and balancing VO involvement for VBE members. However, specification of the VBE-ontology is only the first step in response to these challenges. As addressed in Section 1.2.3, further to the VBE-ontology specification, we also need to develop a system to manage this ontology, which we call Ontology Discovery and Management System (ODMS). The VBE-ontology together with the ODMS represent the conceptual and functional parts of our ColOnto (Collaborative networks Ontology) system addressed before. The main contribution of this Chapter is addressing the design and specification of only the conceptual part of ColOnto, while the functional part of ColOnto is addressed in the Chapter 4 of this thesis.

This Chapter consists of two main sections of 3.2 and 3.3. Section 3.2 addresses the specification and construction of the VBE-ontology. Section 3.3 provides details on the specification of one fundamental part of the VBE-ontology, namely the profile and competency sub-ontology, which also addresses the IVth challenge mentioned above. Finally, Section 3.4 outlines the conclusions of this chapter. Detailed specifications of several parts of the VBE-ontology are presented in Annex D and Annex E of this thesis.
Chapter 3 addresses two out of the three research questions indicated earlier in the thesis in Section 1.5, namely:

**RQ1.** Can we identify the scope and elements of the ontology encompassing wide variety of VBE related entities and concepts, so that it represents the inherent diversity in its subspaces, addressing all endogenous elements and exogenous interactions of the VBE reference model, and specifically the subspace of profile and competency management?

**RQ2.** Can we capture, organise, and specify the large set of diverse but interrelated aspects identified in RQ1 within the VBE-ontology, considering both their evolutionary nature and the heterogeneity of their sources?

The research question RQ1 is addressed in Section 3.2.2, through the definition of the scope of the VBE-ontology, while the question RQ2 is addressed in Section 3.2.3, through the definition of the structure and design of the VBE-ontology.

## 3.2. VBE-ontology

To develop the VBE ontology, we have introduced a methodology rooted in the methodology suggested in [51] and [52] (see Chapter 1, Section 2.2.1 for more details) for the construction of unified ontologies for enterprises. We have however needed to extend the “Building” step, in order to address specificities of developing large environmental ontologies such as the one needed for VBEs. Our extended methodology consists of the following set of steps, also illustrated in Figure 3.1.

- **Step 1. Purpose and definition.** Specification of the purpose is the starting point for engineering an environment ontology. The main uses and a range of intended users for the VBE-ontology are specified at this stage.

- **Step 2. Formality.** At this step, the level of formality for the VBE ontology is defined, and the language for its construction is suggested.

- **Step 3. Scope / Subject matter.** This step defines what should and should not be included in the VBE-ontology out of the wide variety of heterogeneous concepts related to the endogenous and exogenous aspects of the VBE environments. This step particularly specifies the main areas of environment concepts which need to be included in the VBE-ontology, and answers the research question RQ1 of this thesis. For this step, as well as for the next step, the ARCON’s CNO reference modelling framework [17] is applied.

- **Step 4. Building/specification.** This is the main step of the VBE-ontology construction. It includes five different sub-steps. The last two sub-steps are taken from the methodology of Uschold, while we have introduced the first three sub-steps to represent the features specific to the VBE-ontology.
  - **Step 4.1. Design.** This step defines the organisation (including the physical organisation) of concepts in the VBE-ontology. It is required owing to the large scope of the VBE-ontology identified at the previous step. This task which also addresses the research question RQ2 of this thesis. The design approach is based on the results of the previous step of scope definition and specially aiming to address RQ2.
  - **Step 4.2. Applicable sources and techniques identification.** This step defines the types of sources (i.e. literature, text-corpora, databases, schemas, human expertise) out of which the related concepts to the VBE-ontology can be discovered. It also identifies and defines the techniques for discovery and transfer of the identified concepts from their source to the VBE-ontology.
  - **Step 4.3. Ownership & access rights assignment.** This step addresses the issues of sharing and updating the VBE-ontology by multiple stakeholders. This is important
due to multiple user types involved in the VBEs and the compound structure of the VBE-ontology as defined at the design step.

- **Step 4.4. Concepts capturing / Textual specification.** This step addresses textual representation of discovered and defined concepts for the VBE-ontology. We have specified more than 170 concepts in this thesis, which are represented in Annexes D and E.

- **Step 4.5. OWL coding.** This step addresses the development of the VBE-ontology in one specific ontology language, namely in OWL, which is chosen for this thesis.

**Step 5. Evaluation.** At this step the VBE-ontology is evaluated by being assessed as to how it responds to the generic and specific requirements addressed in Chapter 2.

Below we further describe the Steps 1 to 4 of our approach. The Step 5 (evaluation) is not addressed in this section, rather it is addressed in Chapter 5 of this thesis.

---

**3.2.1. Step 1 - Purpose and definition**

As addressed in Chapter 1, Section 1.2.3, the main purpose for developing the VBE-ontology is to respond to the challenges of the VBE information modelling and management, including the four identified challenges of: establishment of a common understanding, VBE...
instantiation in different domains, supporting dynamism and scalability in VBEs, and boosting and balancing VO involvement of VBE members. Based on [52], this step of the methodology should also define the possible users for the VBE-ontology. Our main targets for developing the VBE ontology are summarised below. These are partially extracted from the list of reasons for using ontology in VBEs (from Section 1.2.3), and further include the VBE user concerns:

**Main targets for development of VBE-ontology:**

- **Establishment and support of a common understanding:**
  - Representation and definitions of all VBE concepts and relationships among concepts
  - Introducing linguistic annotations such as synonyms and abbreviations to resolve the problem caused by different names for the same concepts

- **Support for VBE instantiation:**
  - Semi-automated conversion of VBE ontology into database schemas at different domains
  - Semi-automated parameterisation of generic VBE management tools at different domains

- **Support for VBE dynamism and scalability:**
  - Semi-automated processing of knowledge in the VBE ontology by software tools
  - Semi-automated knowledge discovery from text-corpora (sources used for ontology specification)

- **Balancing and boosting VO involvement for VBE members:**
  - Modelling organisations’ profiles and competencies in VBEs within the VBE-ontology to support automatic search and discovery

**Main groups of users for the VBE-ontology and their concerns:**

- **Human users - actors**
  - All stakeholders (including those related to any VBE as well as those outside VBEs) that need to familiarise themselves with the VBE terminology and concepts
  - VBE database developers that need support with development of database schemas
  - VBE administrators and domain experts that need to parameterise the VBE management sub-systems with specific domain data
  - VBE administrators and domain experts that need to obtain data to insert into the VBE management sub-systems (i.e. profile data of VBE member organisations)

- **Software users - tools**
  - VBE management sub-systems, e.g. VBE trust management system or partner search tool, that require a set of semi-automated data processing and discovery functionalities
  - Software tools which are used to maintain / expand the VBE-ontology itself
  - Software tools which enable a variety of VBE actors to display/view/navigate the VBE-ontology, necessary to familiarise themselves with the VBE concepts

Based on the above, the generic definition for the VBE-ontology is provided in Definition 1.

**Definition 1:** VBE-ontology provides a unified and formal specification of the heterogeneous concepts in the VBE environments, allowing these concepts to be easily accessed by and communicated between the human and the application systems, for the purposes of VBE knowledge modelling, collection, processing, analysis, and evolution.
3.2.2. Step 2 - Formality

As earlier addressed in Chapter 2, Section 2.1.1, the VBE-ontology is developed lightweight [23], i.e. it does not support axioms and reasoning. However, its concepts specification need to be formalized so that they can be processed by variety of software tools. For this reason, OWL is selected as the implementation language, which supports defining both the lightweight and heavyweight ontologies, and is commonly used by ontology developers.

Moreover, inspired by [71], which presented an approach to formally define an organizational competency model, we developed an approach to define the VBE-ontology using set theory.

3.2.3. Step 3 - Scope / Subject matter

Addressing the scope is the first step towards specification and engineering of the VBE-ontology. Scope indicates the subject matter of the VBE-ontology [51] and how far it extends. This also aims to respond to the research question \textit{RQ1} formulated in Chapter 1 of this thesis: \textit{Can we identify the scope and elements of the ontology encompassing wide variety of VBE related entities and concepts, so that it represents the inherent diversity in its subspaces, addressing all endogenous elements and exogenous interactions of the VBE reference model, and specifically the subspace of profile and competency management?}

The two techniques of: developing usage scenarios and brainstorming with stakeholders are usually used to define the scope of an ontology [51]. In our approach, a set of ideas for the scope definition is extracted from the purpose of the VBE-ontology (see Section 3.2.1), from the VBE stakeholders’ requirements for the VBE-ontology (see Section 2.4.2.1), as well as from the study of related works (see Section 2.2.2.1 on related ontologies and Section 1.2 about the VBEs). The main elements contained in the scope of our VBE-ontology are summarised below:

a. All elements and concepts that define the VBE environment in the ARCON reference model
b. Concepts that are common to all the VBEs
c. VBEs’ domain/business area terminology (e.g. for mechanical manufacturing)
d. New VBE related technological/scientific terminology appearing in the literature from research and the R&D projects (e.g. for 2nd generation VBEs)
e. European and international norms and standards to be adapted for use by the VBE actors
f. Metadata for the data stored currently or to be stored in the 2nd generation VBE databases
g. Classes of information used in the VBE management subsystems
h. VBE’s Performance Indicators (PIs)
i. VBE’s Collaborative Opportunities (COs) descriptions
j. VBE’s profile and competency models

The above list represents heterogeneous groups of concepts needed to be addressed by the VBE ontology. Concepts in these groups are of a different nature (e.g. organisation’s profile elements vs. business domain terminology). For some groups, their concepts still need to be discovered and specified, while for some others, some standards are already defined. This is why the extendibility of the VBE-ontology is one of main requirements.

To define the scope of our VBE-ontology, the following two main characteristics of the VBE information / knowledge are applied, namely \textit{reusability of information by different
VBE applications and reusability of information needed within different VBE management functionalities. These groups are further addressed below.

**Reusability among different VBE applications.** In order to support the instantiation and operations of the VBEs in variety of application domains, we have divided all VBE concepts into two main groups of domain-dependent information and domain-independent information. We have thus introduced two “concept-reusability levels” or “abstraction levels” for VBE information. They are defined below and illustrated in Figure 3.2.

**Definition 2: Concept-reusability level** partitions the VBE-ontology into two sets/levels of concepts to represent that they can be reused: (1) by all VBEs – core level, or (2) by all VBEs from the same domain / area of activity – domain level.

- The **core level** of the VBE information constitutes concepts that are common to all VBEs and independent of their application domains, for example concepts such as “resource”, “competency”, “product”, “practice”, etc.
- The **domain level** of the VBE information constitutes those concepts that are specific to VBE application domains, for example concepts such as “turn lathe”, “drilling”, “metal parts”, “computer aided design practice”, etc. related to metalworking domain. Domain level concepts are resulted from population of the core concepts to each specific VBE domain environment.

The domain level of the VBE concepts can have a variety of “specialized domain levels” – one for each related sector / business area (e.g. metalworking, healthcare, etc.).

**Figure 3.2: Levels of reusability of VBE information**

This Figure illustrates the core level and domain level of the VBE information reusability. Namely, it points out that there is only one core level, which is common for all VBE application domains. It also points out that there are many specialized domain levels - one per each application domain. The two blocks in the left part of this Figure represent the block of VBE information sources introduced earlier in Chapter 1 in Section 1.1 and Figure 1.1.

**Reusability among different VBE management functionalities.** The functional dimension of the ARCON reference model for VBEs (as presented in Chapter 1, Section 1.2.1.2) addresses a number of VBE management functionalities, such as VBE membership management, profile and competency management, trust management, etc. In order to support
the management of information related to different VBE management functionalities, we have divided the VBE concepts into a number of sub-groups in such a way that each specific management functionality is almost entirely represented by one specific sub-group of concepts. Based on definition of VBE functionalities, we have introduced ten main sub-groups of VBE concepts, that are described below and illustrated in Figure 3.3. Also, applying the notion of “work areas” presented by Uschold for development of his AIAI enterprise ontology [72], we call these ten sub-groups of concepts VBE-ontology “work areas”. Our work areas however have a different nature than those of the AIAI enterprise ontology. For instance, the work areas identified for the VBE-ontology have larger scopes.

**Definition 3: Work area** is a partition of the VBE-ontology that includes the set of concepts while can be reused within one specific process/functionality of the VBE management, i.e. related to specific VBE management service, functionality, tool, or task.

Please note, that each of the defined work areas from 2 to 9 support a specific VBE management functionality, while the work area 1 serves for integration of the above eight work areas, and the work area 10 specifies the information related to the VBE management system itself. The concepts for work areas 1, 2, and 3 mainly address the ARCON’s structural dimension. The concepts for work areas 4 to 8 mainly address the ARCON’s componential dimension. The concepts for work area 9 are taken from ARCON’s behavioural dimension. And the concepts for work area 10 represent ARCON’s functional dimension.

<table>
<thead>
<tr>
<th>1. VBE-self</th>
<th>2. Virtual Organization</th>
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<tbody>
<tr>
<td></td>
<td>3. VBE actor / participant</td>
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<tr>
<td></td>
<td>4. VBE profile and competency</td>
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<td></td>
<td>5. VBE history</td>
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<td></td>
<td>6. VBE bag of assets</td>
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<td></td>
<td>7. VBE trust</td>
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<td>8. VBE governance</td>
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<td></td>
<td>9. VBE value system</td>
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<tr>
<td></td>
<td>10. VBE management system</td>
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</tbody>
</table>

To use in the Profile and competency management system (PCMS)

**10 work areas**
(support for specific VBE management sub-systems)

**Figure 3.3: Work areas of VBE information**

*This Figure illustrates the ten groups of concepts for the VBE-ontology called “work areas”. The work areas from 2 to 8 support specific management functionalities of the VBE management system. The work area 1 serves for integration of work-areas 2 to 8. And the work area 10 defines the VBE management system itself. The image on the left side of this Figure is a shrunk version of VMS representation, which is addressed further in Chapter 4 as Figure 4.1. The work area 4 is darkened to emphasise that it plays an important role in the design of PCMS system addressed in this thesis as a solution for the research Challenge 4.*

1. The **VBE-self** work area includes the main concepts characterizing the VBE network as a whole. For example, these concepts include the “VBE” concept itself and the concepts,
defining the main elements/components constituting a VBE, such as “VBE Actor” and “VBE Governance”.

2. The Virtual Organization work area includes the main classes of knowledge characterizing a Virtual Organization and involved in VO information management functionalities in VBE. For example, it addresses the main attributes of VOs, such as “VO Partner” and “VO Model”.

3. The VBE actor/participant work area includes main concepts characterizing VBE actors, and aims at supporting the VBE membership management functionality. For example, it addresses the main attributes of the VBE actor class, such as “VBE Actor Profile” and “VBE Actor Role”, as well as including a classification of multiple roles that VBE actors play in the VBEs, such as “VBE Member”, “VO Broker”, etc.

4. The VBE profile and competency work area includes concepts characterizing the VBE member’s profile and competency, and aims at supporting the profile and competency management in VBEs. It addresses elements of the VBE member organization’s profile such as “Competency”, “Resource”, “Practice”, etc.

5. The History and inheritance work area includes concepts characterizing the VBE historic information, and aims to support functionalities for management of history of VBE members, VOs, and the VBE-self. For example, it addresses the types of the VBE history, such as “VO Inheritance” and “VBE Actor’s History”, as well as the main sub-components of the VBE actors’ history, such as “Cooperation” and “Collaboration History”.

Figure 3.4: Relationships among work areas of the VBE-ontology
This Figure illustrates the type-of relationships among the main concepts of the ten work areas. Namely it addresses the fact that a VBE has the following interrelated work areas: VBE actors, VOs, Governance, VMS (VBE management system), Bag of assets and Value system. In turn, VBE actors and VOs have History, while the VBE actors also have Profiles and Trust. Moreover, value System and Governance also represent components of the bag of Assets.

6. The VBE Bag of Assets work area includes concepts characterizing the main types of documents and software tools available in the VBE’s accumulated bag of assets and aims to support functionality for the bag of assets management. The concepts in this group include for example “Lessons Learned”, “Commercial Software” and “Document of Interest”.

72
7. The **VBE Trust** work area includes concepts to characterize trust establishment in VBEs and aims to support the trust management functionality in VBEs. For example, it presents the definition of “VBE Trust” through “Trust Objective” and “Trust Perspective”. It also presents two classes of “Trust Actors” in VBEs such as “Trustee” and “Trustor”.

8. The **VBE Value System** work area includes concepts for characterizing VBE’s system of values and capitals, and aims to support the VBE value management functionality. For example, it defines the components of the VBE Value System such as “Value Generation Objects” and “Performance Indicator”.

9. The **VBE Governance** work area includes concepts characterizing VBE rules, bylaws, principles and VBE collaboration culture. For example, it defines the sub-classes of the “VBE Bylaw” class such as the “Conflict Resolution Policy” and “ICT Use Guideline”.

10. The **VBE management system** work area includes the main concepts defining the VBE management system as a whole. It includes concepts such as “Trust Management System”, and “Agreement Negotiation Wizard”.

   Please note, that some concept addressed in different work areas may belong to more than one work area. For example, the concept of “Profile” can belong to both the “VBE actor/participant” work area and to the “VBE profile and competency” work area. Figure 3.4 illustrates the type-of relationships among these ten sub-ontologies through also reflecting the relationships defined among their main concepts.

   The ten work areas of the VBE-ontology are complementary and each has some concepts that it shares with some other work areas. In addition, while these ten work areas comprehensively capture all concepts related to different functionalities in the 2\textsuperscript{nd} generation VBEs, it is clear that in future when and if needed more work areas can be defined and added to the VBE-ontology, while also specifying their interrelations with other work areas.

   Additionally, each of these ten work areas can also split into smaller work areas depending on the level of details which may be needed to be captured by them. For example in the Profile and Competency work area, the Competency work area can be separated from the Profile work area, if their details need to be drastically expand for one VBE.

### 3.2.4. Step 4 – Building

The building step includes a set of sub-steps that lead to construction of the VBE-ontology from its design phase to the actual building up of the physical OWL ontology. In the previous Section we pointed out that the scope of the VBE-ontology is large and its concepts have heterogeneous nature. This is the main reason why both designing of the VBE-ontology on a detailed level, and finding a suitable approach for its construction were the most challenging tasks in our research. At this step, we have also answered to the research question \textit{RQ2} formulated in the thesis: \textit{Can we capture, organise, and specify the large set of diverse but interrelated aspects identified in RQ1 within the VBE-ontology, considering both their evolutionary nature and the heterogeneity of their sources?}

#### 3.2.4.1. Step 4.1 - Design

In order to make a detailed design of the VBE-ontology, we have gone further with our idea of grouping all possible VBE-concepts into smaller groups, and designing them inside these groups. Namely, we have applied the divide and conquer principle in order to simplify coping with the large size and the wide variety of aspects. Our design for the VBE-ontology is based on the “ontology partitioning” approach [73] and dividing various aspects on both the logical and physical levels. Our approach for partitioning is addressed below in this section. This partitioning resulted into representation of the VBE-ontology as a set of “sub-ontologies” which are also defined in this section. We also explain the way in which
the VBE-ontology for every specific VBE application environment shall be assembled out of a number of sub-ontologies.

**Sub-ontologies.** The previous Section addressed the scope of the VBE-ontology through grouping its concepts into the two concept-reusability levels and the ten work areas. The results of intersection of the “horizontal” reusability levels and the “vertical” work areas are introduced in this thesis as **sub-ontologies** of the VBE-ontology.

**Definition 4. Sub-ontology** is a partition of the VBE-ontology representing on one hand an independent physical unit, i.e. that can be used independently by VBE’s human and software agents, but on the other hand its complementarity to other sub-ontologies, i.e. the fact that all sub-ontologies together comprise the complete VBE-ontology.

Similar to work areas, sub-ontologies may also be further split into a set of “sub-sub-ontologies”. For example from the “Core level Profile and Competency sub-ontology”, the “Core level Competency sub-sub-ontology” can be separated. Therefore, a “sub-sub-ontology” describes a smaller work area but the same concept-reusability level. Splitting a sub-ontology depends on the convenience of engineering and processing of the smaller partitions instead of the entire sub-ontology by software and human agents. Please note that in relation to the entire VBE-ontology, in most cases there is no difference between “sub-ontologies” and “sub-sub-ontologies”, thus the “sub-sub-ontologies” can be also referred to as “sub-ontologies”.

The sub-ontologies represent the minimal physical units of the VBE-ontology, i.e. physical OWL files on a computer, while the whole VBE-ontology itself shall be assembled from its physical sub-ontologies according to its logical structure. Therefore, the VBE-ontology at the physical level represents an assembly of independent but complementary sub-ontology files.

One benefit of building and maintaining sub-ontologies is to support incremental development of the VBE-ontology by a number of different ontology developers. Therefore, while some sub-ontologies are still under development, the developed sub-ontologies may be used to support VBE information management in both new and running VBEs. This especially applies to the domain level sub-ontologies that need to be constructed on demand, when a new VBE needs to be established in a specific domain. Only the core level sub-ontologies should be established independently of any VBE applications.

Below is a list of the main characteristics of the domain-level sub-ontologies that make the decomposition of the VBE-ontology indispensable:

- **Usability variety.** The VBE domain sub-ontologies may totally differ from one VBE domain to another. Namely the competencies of organisations in a manufacturing domain, completely differ from the competencies of an organisation in a healthcare domain.
- **Source variety.** Some standards / classifications of knowledge may already exist for some of the business/industry domains, e.g. [74], which can contribute to the construction of the VBE domain level sub-ontologies. However, this is not the case for all VBE domains.
- **Dynamism variety.** The VBE domain sub-ontologies need to be continuously extended during the VBE operation/evolution stage, in order to support the VBE’s dynamism.
- **Content variety.** The knowledge in the VBE domain sub-ontologies primarily includes all the knowledge related to the specific domain / business area of the VBE, as well as all the relevant knowledge collected from the VBE members / actors.
- **Dynamism level.** The dynamic nature of the VBEs makes it difficult for human VBE experts to continuously monitor and collect the new domain data that is brought to the VBE by the newly joined actors and/or new business opportunities in
the market/society, which subsequently must be introduced within the VBE domain sub-ontology.

- **Reusability variety.** The domain level sub-ontologies shall be reusable by the VBEs from the same domains.
- **Actors variety.** The domain sub-ontologies must be developed and evolved in commitment with all actors in the same domain.

**Sub-ontologies for a specific VBE application.** Earlier in Section 3.2.3 we outlined that the domain level of the VBE-ontology is represented by a number of specialised domain levels – one for every domain or business area of activity. To support a specific VBE application however, its management does not need to apply the entire domain level ontology, rather usually only a subset of the specialised domain levels is required, in which this VBE operates. Therefore, every VBE requires its own “exemplar” of the whole VBE-ontology including a part of its domain ontology. We define of our VBE-ontology exemplar as following:

**Definition 4. An exemplar** of the VBE-ontology is a partition of the entire VBE-ontology that represents: (1) the whole core level of the VBE-ontology, and (2) a subset of specialised domain levels from the specific domains, in which the VBE operates.

3.2.4.2. Step 4.2 - Applicable sources & techniques identification

A number of existing sources can be used for acquiring concepts for the VBE-ontology. For example, the knowledge of VBE experts, reference books about VBE activity domains, research publications, databases and web-sites of existing VBEs, etc. Every type of source requires a specific technique for extraction/discovery of concepts. There are four main types of techniques usually applied, including: (1) manual development, (2) existing ontologies integration, (3) reverse engineering, and (4) natural language parsing (as described in Annex B, Section B.1.4).

The sources and techniques differ for the core level and domain level of the VBE-ontology. Since the concepts for the core level are common for all VBEs, they need to be specified objectively. Therefore, the terms cannot be taken only from the practice of either one specific VBE or a set of VBEs from the same domain. Furthermore, since the research on VBEs is still ongoing, new types of generic terminology are still being introduced. This terminology in some cases replaces the earlier terminology used for these networks. Therefore, for the core level terminology we apply the VBE reference model [9].

Finding terms and concepts for the ontology of the VBE domain level is usually easier than for the core level, since in most domains (e.g. metalworking, healthcare) their terminology is already specified and standardised in specialised domain literature, e.g. reference books, taxonomies, etc. Domain concepts mainly represent sub-classes of the core-level concepts, for example a hierarchy of domain related business processes can be formed for the profile and competency work area. Furthermore, the terminology for the domain level sub-ontologies can be extended with the involvement of domain experts.

A set of reusable sources and techniques, for building the VBE-ontology, are illustrated in Figure 3.5 and defined in more details in this section.

1. **Experts’ knowledge (to reuse by manual development techniques)**
   - **K1:** Knowledge of work area experts, including:
     - Publication about specific work areas, namely about modelling and management of trust between companies, management of profiles and competencies of organizations, modelling of value systems, etc.
• K2: Knowledge of VBE experts, including:
  - Knowledge and expertise of the academia experts working in the area of collaborative networks and VBEs in particular.
  - Knowledge and expertise of the administrators, coaches, technical support providers, and other members of existing VBEs.

• K3: Knowledge of domain experts, including:
  - Knowledge of domain experts working for networks of companies or single companies operating in a specific domain.

2. Other ontologies (to reuse by ontology integration techniques)
• O1: Existing work area ontologies, including:
  - Ontologies introduced by the earlier research related the VBE, for example the VO performance indicators ontology (as addressed in annex B, Section B.2.2)

• O2: Existing domain ontologies, including:
  - Ontologies that exists for some domains of activities, for example the GENE ontology [75] for the biodiversity domain

3. Structured sources, e.g. DB schemas, taxonomies (to reuse by reverse engineering techniques)
• S1: Schematic assets of work areas, including:
  - Database schemas and data models from the related work areas, such as organizations’ competency management (e.g. as addressed in B.4.2.1),

• S2: Schematic assets of running VBEs, including:
  - Database schemas, ontologies, diagrams, and information collection forms of existing VBEs.

• S3: Domain schematic assets, including:
  - Database schemas and data models developed and used by organizations, institutions or consortiums working in a specific domain of activities.

4. Semi-structured and unstructured sources, e.g. web pages, dictionaries) (to reuse by natural language parsing techniques)
• U1: Domain reference books and web-sites, including:
  - Reference books, dictionaries, standard specification, and other domain literature describing domain information, such as terminology, taxonomy, definitions, etc.

For building up the core level of the BE-ontology, as well as several domain sub-ontologies for the manufacturing domain level, we reused the following sources:
• For the core level sub-ontologies:
  - Expertise of academia experts from organisations representing partners of the ECOLEAD project and members of the SOCOLNET society
  - Expertise of VBE representatives from existing VBEs participating in the ECOLEAD project
  - Reports and publications of the ECOLEAD project [76], particularly, the main concepts were extracted from [14]
  - Diagrams and information collection forms from existing VBEs participating in the ECOLEAD project

• For the domain level sub-ontologies:
  - NACE classification of business activities.
  - Data categories from the management tool of the metalworking domain VBE from Mexico called IECOS
  - Knowledge of experts working in the metalworking domain, particularly from Mexico and Switzerland
  - Reference books for metalworking domain
**Core level of VBE-ontology**  
*Develop prior to and independently of any VBE application*

- **K1:** Knowledge of work area experts  
- **K2:** Knowledge of VBE experts  
- **O1:** Existing work area ontologies  
- **S1:** Schematic assets of work areas  
- **S2:** Schematic assets of running VBEs  
- **K3:** Knowledge of domain experts  
- **O2:** Existing domain ontologies  
- **S3:** Domain schematic assets of running VBEs

**Domain level of VBE-ontology**  
*Develop on demand*

- **U1:** Domain reference books and web-sites  
- **Parsing**  
- **K3:** Knowledge of domain experts

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**Figure 3.6:** Sources and techniques for building up the VBE-ontology

This figure illustrates nine main sources for acquiring concepts for the core and domain levels of the VBE-ontology, such as experts’ knowledge, existing database schemas, existing ontologies, etc. For each source, its related technique for concepts discovery is also illustrated.

The four types of techniques are introduced in Figure 3.6 below in more detail:

**a) Manual development by experts.** This technique for engineering sub-ontologies is based solely on the experts’ knowledge. In annex B, Section B.1.4 five approaches for manual ontology building are addressed. The choice of an approach depends on the specifics of a sub-ontology, as follows:

- The *Inspiration approach* is suitable for sub-ontologies that can be only developed from scratch, such as the sub-ontologies for the VBE-self work area and the VO work-area.
- The *Induction approach* is suitable for development of all core level sub-ontologies based on cases of existing VBEs.
- The *Deduction approach* is suitable for development of all domain level sub-ontologies after their related core level sub-ontologies are developed.
- The *Synthesis approach* is suitable for integration of all developed sub-ontologies.
- The *Collaboration approach* is suitable for making a convention by a number of experts on all VBE related concept names as well as on the structure of all sub-ontologies.

**b) Existing ontologies integration.** There are many approaches for integration of ontologies (as addressed in Annex B, Section B.5.1). However, for core level sub-ontologies there is a small number of existing ontologies that can be reused for integration. But, the domain level ontologies exist for many of the wide variety of activity domains.
c) **Reverse engineering.** There are a number of existing database schemas and other models related to the VBEs. Namely, some running VBEs can provide their database schemas for reuse. They also use some forms for collecting data from their member organisations. These resources are in specific predefined format, which means they can be processed by a software tool, for their terms to be extracted and organised in an ontological format. For every resource format, a reversing/converting software tool shall be developed.

d) **Shallow NL parsing.** For the semi-structured resources that are represented in the form of reference books, dictionaries or taxonomies, extraction of concepts from these resources can also be semi-automated. An example semi-automated concepts discovery tool called tOKo, which we have also used for extension of the VBE-ontology, as briefly addressed in annex B, Section B.5.2.

### 3.2.4.3. Step 4.3 - Ownership & access rights assignment

Since the sub-ontologies of VBE-ontology are developed to be distributed and shared among different VBEs, the issue of ownership, access rights, and confidentiality needs to be addressed.

In relation to the core level of the VBE-ontology that is developed to be common for all VBEs, it should not be owned by any specific VBE, but instead by an external institution that develops and maintains. Therefore, the access rights for editing these levels should belong only to that institution, while the access rights for loading and processing these levels should belong to all varieties of their possible users. Furthermore, these levels are not confidential.

In relation to every exemplar of the domain level of the VBE-ontology, its sub-ontologies can be owned either by some external institutions or by specific VBE networks. The institutions owning some domain level sub-ontologies shall represent domain experts. They shall have the access rights for editing their sub-ontologies, while access rights for loading and processing these sub-ontologies should belong to all varieties of their possible users. The VBEs owning some domain level sub-ontologies either keep them confidentially or share them with their collaborators. They can also provide their sub-ontologies to others together with the editing rights. Then such “copies” of sub-ontologies can exist and evolve independently as separate sub-ontologies.

### 3.2.4.4. Step 4.4 - Concepts capturing / Textual specification

This Section describes the approach that we used for capturing of concepts and textual specification of all core level sub-ontologies as well as a number of domain level sub-ontologies.

**Concept capturing.** Considering that different stakeholders within VBEs may use its terms flexibly (i.e. with varying meanings), and moreover some of the terms specified in the VBE-ontology may not be the obvious choice for a certain concept in a certain VBE environment, our main goal when defining a concept is to provide variety of synonyms as well as other annotations for it. Furthermore, annotating concepts, as well as defining relations between them, also supports integration of sub-ontologies developed by different developers within the whole VBE-ontology.

When annotating a concept, we kept in mind that concept definitions in ontologies are typically different from definitions in dictionaries [72]. While dictionary definitions report how words are used, ontology definitions often report how a limited set of terms are used in relation to each other. Therefore, understanding an ontology requires a willingness to dispense with preconceptions based on the dictionary meaning and/or other common usage of terms. This is why we prefer to use terminology from literature / publications when labelling concepts from the core level. But we also prefer to use specific terminology from running VBEs’ application environments as synonyms for concepts.
The types of annotation introduced for the VBE-ontology include the following:

- **Concepts annotations**
  - “Label”: The Label of a concept in the VBE-ontology is either one word or a short phrase written in the rules of a natural language, representing this concept. The Label represents the term that is intended to be used and shared by different VBEs. While the same concept can be expressed through different terms in different VBEs, its label is intended to represent a kind of standard uniform representation of the concept. The label can be different from the machine representation of the name of the concept, since most ontology editors do not allow spaces in the names of concepts (they are usually replaced by dashes), while labels are written in a natural language. Labels in the VBE-ontology are intended for understanding by both: human actors and software components.
  - “Definition”: The Definition of a concept in the VBE-ontology is a textual explanation of the meaning of this concept. The main purpose of the definition is to be read and understood by all VBE stakeholders.
  - “Synonym”: A Synonym of a concept in the VBE-ontology is any word or a short phrase written in the rules of a natural language that is used in some VBEs or in other contexts for expression of this concept, but is not equal to the label of this concept. A concept can have many synonyms representing different terms or words used in speech or in documents for expression of this concept. Similarly to labels, synonyms in the VBE-ontology are used for understanding by both: human actors and software components.
  - “Abbreviation”: An Abbreviation in the VBE-ontology represents the abbreviated form of a label or a synonym of a specific concept. One concept can have many abbreviations. The abbreviations are also intended to be used by both human actors and software components.
  - “Kind”: The Kind of the concept represents a modelling aspect for the concept. The following four kinds of concepts are defined based on the ARCON model: Active Entity, Passive Entity, Function, and Concept.
  - “Sub-ontology”: This property addresses the name of one of a set of sub-ontologies to which a concept belongs.

- **Relationships annotations**
  - “type of”: Many concepts of the VBE-ontology are organised in hierarchies, i.e. they have the ”type of” (also-called “hyponymy” or “subsumption”) relation. For example, “VBE actor” has a subclass “Regular VBE member”.
  - “has part”: Many entities in VBE environments are constituted of other entities, i.e. have the “aggregation” (also-called “meronymy”) relation. For example, every “Profile” has “Competency” as its part.
  - “has attribute”: This is the “association” relation which connects other semantically related entities, that cannot be connected with the “type of” or “pas part” relations. For example, every “VBE actor” has a “Role” as its attribute.

**Textual specification.** The textual specification of the developed sub-ontologies of the VBE-ontology, addressed in our research, is organized specially for the sake of easier visualisation of the concepts’ characteristics and for publishing the VBE-ontology in academic proceedings. This Section briefly addresses this specification, while the complete set of VBE-ontology specifications are presented in annexes D and E of this thesis.

In our VBE-ontology research, all ten sub-ontologies of the core level are defined. Also, a few specialised domain level sub-ontologies are specified as examples. Please note that in
Annex D, for some core level sub-ontologies, definitions of several of their “secondary” concepts are skipped due to the space limitation in the thesis. Particularly, some concepts are only mentioned while their details are not provided. In this case the phrase “(is not presented)” appears next to such concepts. Annex E gives two example domain level sub-ontologies developed for the manufacturing domain, namely (1) the sub-ontology for automatic machining processes and (2) the sub-ontology for manufacturing practices. Both sub-ontologies can be reused by VBEs operating in the domain of manufacturing activities. Our main innovative contribution in relation to the specified VBE-ontology is related to modelling VBE competencies, a main part of the VBE core level ontology.

3.2.4.5. Step 4.5 - OWL coding

The sub-ontologies of the VBE-ontology are implemented using two ontology editors – Hozo [77] and Protégé [78]. Hozo is a graphical ontology editor and ontology viewer environment that has a user-friendly interface that supports building of ontologies. Protégé is an extensive ontology editor that supports OWL ontologies development. For our purposes, first Hozo is used to model VBE concepts and their relationships in a graphical format. Afterwards, Protégé is used to specify the OWL-based features of the VBE sub-ontologies.

The developed core level of the VBE-ontology is represented by ten sub-ontologies (i.e. ten OWL files). The developed domain level of the VBE-ontology includes several example sub-ontologies developed specifically for the manufacturing domain example, as applied in the ECOLEAD project.

![Figure 3.7: Partial screen-shot of the VBE profile and competency ontology at the core level](image)

This Figure shows a part of the VBE profile and competency sub-ontology at the core level, represented using the graphical Hozo editor. In this editor, the concepts are represented by boxes, while the three types of relationships are represented by connectors. The “is-a” connector stands for the “has subclass” relationship. The “p/o” connector stands for the “has part” relationship. And the “a/o” connector stands for the “has attribute” relationship.

A few screen-shots from these sub-ontologies are illustrated below. Figure 3.7 demonstrates a part of the VBE profile and competency sub-ontology of the core level, represented with the graphical Hozo editor. In this editor, the ontology concepts are represented by boxes, while the three types of defined relationships are represented by...
connectors. The “is a” connector stands for the “has type” relationship. The “p/o” connectors stand for the “has part” relationship. And the “a/o” connectors stand for the “has attribute” relationships.

![Image of the Protégé editor](image)

Figure 3.8: Screen-shot of the manufacturing practice sub-ontology of the domain level. This figure shows the manufacturing practice sub-ontology of the domain level represented in the Protégé editor. On the left-hand side, Protégé displays a catalogue of ontology concepts, where the concepts are located according to their “has subclass” relationships. On the right-hand side, Protégé displays the meta-properties, attributes and other relationships of concepts.

Figure 3.8 addresses the manufacturing practice sub-ontology of the domain level represented in the Protégé editor, as an example for domain level ontology. On the left-hand side, Protégé displays in one tab a catalogue of the ontology concepts, where the concepts are located according to their “has subclass” relationships. On the right-hand side, Protégé displays the meta-properties, attributes and other relationships of the concepts in a number of tabs.

### 3.3. Profiles and competencies

This Section provides details about the engineering of one sub-ontology of the VBE-ontology, namely the “core level profile and competency sub-ontology”. We developed this sub-ontology on top of the models for profiles and competencies of VBE member organisations. Its main goal is to facilitate management of characteristic information about VBE member organisations. Specifically, this Section addresses the approach which we developed for identification of this sub-ontology’s concepts and the relationships among these concepts from different types of sources (see Section 3.2.5). It also addresses the engineering of domain level sub-ontologies related to this core-level sub-ontology.

Detailed addressing of the development of core level profile and competency sub-ontology represent an example for how other sub-ontologies are developed, and specifically exemplifies how much details are involved in the research, related to every work area and every VBE sub-ontology.

Further below in this section, we present both the specification of the profile model in Sub-section 3.3.1, and the specification of the competency model in Sub-section 3.3.2. This Section also discusses the VBE domain variety in relation to the VBE members’ profile and
competency model in Section 3.3.3. The Section also introduces two new concepts of “aggregate competency” and “collective competency” (in Section 3.3.4), which play a role in facilitating VO’s configuration.

In annex F one example for organization’s profile and one example for organization’s competency is provided.

### 3.3.1. Generic model of profile

As addressed in Chapter 1, Section 1.2.2.4, the main objective of the ICT-based design and management of member organisations’ profiles is to facilitate the involvement of VBE member organisations, from some specific line of activities/operations, in creating their profiles semi-automatically. Based on that, the following definition of profile is proposed:

**Definition 6. The VBE member organisation’s profile** consists of specific set of identifying characteristics (e.g. name, address, capabilities, etc.) about each organisation, that are collected specifically to facilitate their semi-automated selection for involvement in some specific line of activities/operations in VOs.

Organizations’ profiles need to be created and kept up to date, due to the following specific reasons:

- **Creation of awareness inside the VBE:** that needs basic information about name, creation date, location, size, area of activity, general textual description of an organisation
- **Configuration of new VOs:** that needs basic information (i.e. name, size, etc.), contact information, competency information and financial information.
- **Evaluation of members by the VBE administration:** that needs records about past activities of organisations including past collaboration/cooperation activities, as well as products/services produced and practices applied.
- **Introduction / advertising in the marker / society:** that needs aggregation of characteristics such as locations, competencies and past history.

To identify a complete set of profile elements, we considered the results of our requirement analysis (Chapter 2). Based on the state of the art (Section 2.2.4) as well as the identified requirements (Section 2.4.5.2), we drew down an embedded list of elements for VBE members’ profiles.

Further in this Section our design of the generic/unified structure of the VBE members’ profile is presented. Sub-section 3.3.1.1 presents the three major categories of profile information, and Sub-section 3.3.1.2 addresses the elements identified for the generic model of VBE member organisations.

The following three major categories of profile information for organizations have been identified:

- **VBE-independent information** includes the organisation’s characteristics that are independent on their involvement in any collaborative and cooperative consortia.
- **VBE-dependent information** includes the organisation’s characteristics that are dependent on their involvement in collaborative and cooperative consortia within the VBEs, VOs, or other types of CNs.
- **Conspicuity documents** are required as the indication / proof of validity of the profile information provided by the organisations, related to both previous categories of information. The conspicuity can be either an on-line document or web accessible information, e.g. organisation’s brochures, website, etc.
A generic model for the VBE member organisation’s profile is developed. Its partial model is presented in Figure 3.9. This Figure illustrates the three main categories of the profile elements, including: (1) VBE-independent information, (2) VBE-dependent information, and (3) Conspicuity documents. Each category has a set of subcategories, such as basic information, legal information, etc. Further, each subcategory has a set of profile elements. Figure 3.9 illustrates elements of each category. Due to the space limitation, this Figure illustrates up to only three elements in each category, while other elements are also named and described below in this section.

Figure 3.9: Partial model of the VBE member’s profile

*This Figure illustrates the main structure of the profile definition. The gray boxes illustrate a few complex objects, e.g. VBE-dependent information and VBE history information, which have other objects as attributes. The white boxes represent objects that have only simple textual attributes.*

Below, Table 3.7 addresses the three categories of profile information in more details. For each category its purpose, main information classes, and other details are provided. Many elements in this profile model are the result of our in-depth study in this area. For each profile information class, its confidentiality level is also defined in the table. Four levels of confidentiality (“Conf. level” in the table header) are identified, namely: (I) visible only to
VBE administration, (II) visible for VBE administration and VBE experts (such as VBE coaches, VO brokers, etc.), (III) visible to all VBE members, and (IV) visible to all VBE members and also to everybody outside the VBE.

Table 3.7: Information classes in the generic model for VBE member organisation profile

<table>
<thead>
<tr>
<th>Information class</th>
<th>Attributes and description of the information class</th>
<th>Conf. level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic information</strong></td>
<td>Basic information represents a minimal set of data identifying and characterising an organisation, including: Name, Locations, Creation date, Domain of activities, Number of Employees, and General Description. Providing the basic information is obligatory for all member organisations at the registration stage in the VBE. The basic data is accessible to the public. Its main objective is to introduce the organisation both inside the VBE and outside the VBE in the market / society.</td>
<td>IV</td>
</tr>
<tr>
<td><strong>Legal information</strong></td>
<td>Legal information represents a set of characteristics of the organisation such as Legal Name, Legal status, Legal address, that can be accessed mainly by the VBE administration and needs to be submitted at the time of application for the VBE membership.</td>
<td>III</td>
</tr>
<tr>
<td><strong>Mission information</strong></td>
<td>Mission information represents the description of the organisation’s Vision, Mission, Strategy, and Targeted Group (i.e. Market/Society sector). This data is mainly used within the VBE to analyse whether or not it corresponds to the common Vision, Mission, Strategy and intended Targeted Groups of the entire VBE.</td>
<td>III</td>
</tr>
<tr>
<td><strong>Contact information</strong></td>
<td>Contact information describes how the organisations can be contracted, such as through: Postal Addresses, Phones, Faxes, E-mails, and Websites. The contact data also provides links to descriptions of Contact People (i.e. individuals within the organisation). The contact information must also be provided when the organisation is registered in the VBE. It is publicly accessible mainly inside the VBE.</td>
<td>II and III</td>
</tr>
</tbody>
</table>
| **Competency information** | Competency information includes different aspects of the organisation’s competency description, including the specification of the competency itself. Namely, it includes:  
• The **Competency** indicates what an organisation can do and is used mainly for the sake of VO creation. The competency model is defined further below in this Chapter in Section 4.4.2.  
• The **Product** represents the description of the variety of services and goods developed, produced, and delivered by the organisation. The main descriptors of the product include: Name, Textual Description, Type (i.e. of product or service), and Production Strategy (e.g. “engineering to order” for goods and “design of services” for services).  
• Resource represents the element applied to a business process in the organisations. Several types of resources can be identified (see Section 4.1.2.1), including: human resources, ICT resources (e.g. software, hardware, and communication facilities), physical resources (e.g. buildings, equipment, machines, transport and recorded information) and organisation resources (e.g. brand and culture). The main descriptors of resources differ from one type of resource to another. For example, the human resource descriptor can include: Job Function, Educational Level, Professional Field, Degree Obtained, | From I to IV |
<table>
<thead>
<tr>
<th>Information class</th>
<th>Attributes and description of the information class</th>
<th>Conf. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Associated partner information</td>
<td>Associated partner information represents a description of a second organisation (e.g. a sister company, a supplier, or a customer) which has some (business) relations with the member organisation. The main descriptors include: Partner name, Type of relationship (with the member organisation), and Duration of Collaboration. The information about associated partners provided in the profiles supports the further invitation of these organisations to the VBE as new members.</td>
<td>From I to III</td>
</tr>
<tr>
<td>Financial information</td>
<td>Financial information about a member organisation is typically required by the VBE in order to verify their financial stability (see Section 4.1.1.1). For instance, the financial stability of a VBE member organisation is important in order to assure the VO broker that the organisation will survive during the VO’s operation. The main descriptors of the financial information include: Total Sales, Total Revenue, Annual Balance and Operational Costs. Financial data collected from the organisations shall be treated with a very high degree of confidentiality, i.e. it can be accessed only by VBE administration and designated partners, e.g. a VO broker.</td>
<td>I and II</td>
</tr>
<tr>
<td>History information</td>
<td>History information represents the record of past events at the organisation. The attributes of History of a member organisation include: a textual History Description, as well as more detail about the History of the Products Produced and Practices Applied. This information is needed mainly by VBE administration and VO brokers to evaluate of this member organisation’s past activities.</td>
<td>From I to III</td>
</tr>
<tr>
<td>VBE-dependent information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VBE registration information</td>
<td>VBE registration information represents the main characteristics of the organisation in relation to the VBE where this organisation is registered, such as Registration ID, Registration Date, and Participation Role. This information is needed by regular VBE members as well as by the VBE administration and VO brokers to see the current position of a VBE member in a VBE mainly for evaluation of this member’s activities in VBEs.</td>
<td>III</td>
</tr>
<tr>
<td>VBE history information</td>
<td>VBE history information represents the record of past events at the organisation in relation to VBE consortium activities, including Collaboration History (i.e. in VOs) and Cooperation History (i.e. in VBEs). This information is needed mainly by the VBE administration and VO brokers for evaluation of this member organisation’s past activities within VBEs.</td>
<td>II and III</td>
</tr>
<tr>
<td>Conspicuity documents</td>
<td>This category is represented here only by one high-level information class, namely the “Conspicuity” class. However, the conspicuity documents can be of two different kinds: the “witnessed evidence” documents (e.g. a letter of recommendation or an article in a magazine/newspaper) or the “authorised / certified evidence” documents (e.g. accreditation statements, financial ratings, licenses, certificates, patents and awards). Evidence documents can indicate the product quality, financial stability, and so on, and they will be kept in the VBE when provided by the organisations.</td>
<td>I and II</td>
</tr>
</tbody>
</table>
3.3.2. Generic model of competency

The main objective of our introduced competency model for VBE member organisations, called the “4C-model of competency”, is to promote the involvement of the VBE member organisations in future VOs [48][50]. While the competency itself is an element of the profile model, it also has an embedded, compound structure. The four fundamental components characterising the competency in this model are designed based on the state of the art study and the requirement analysis in running VBEs. These four represent: “Capability”, “Capacity”, “Cost” and “Conspicuity”. A description for and the reason behind the design of each component in this model, is further addressed below.

Definition 7. Organisations’ competencies in VBEs represent up-to-date information about their capabilities, capacities, costs, as well as the conspicuities, illustrating their accuracy, all aimed at qualifying organisations for VBE participation, and mostly geared towards their VO involvement.

The main features that make up the 4C-model unlike other models (as addressed in Section 2.2.4.2) include the following:
- The 4C-model is developed addressing the context of VO creation within VBEs. Thus, the competency structure and main elements primarily intend to meet the specific VBE requirements, and potential VO qualification.
- The 4C-model is the basis for development of a competency database at the VBE, as well as the system for cataloguing and processing of competencies (i.e. the PCMS). Hence, the competency structure shall support dynamic structuring and processing of competencies.

Figure 3.10 - Generic 4C-model of competency

This Figure illustrates a UML diagram specified for the 4C-model of competency. It addresses the main elements of Competency including: Capability, Capacity, Conspicuity and Costs, as well as two other related elements: Product and Resource.
To properly support the competency-based VO creation in VBEs, sections 3.3.3 and 3.3.4 also introduce two new concepts: the “aggregate competency” and the “collective competency”.

But similar to other competency models addressed in Section 2.2.4.2, the 4C competency model in VBEs also has a compound structure. However, the primary emphasis in this model goes to its four main components. Reasons for design of these elements are introduced below as prerequisites for the 4C-model:

1. **Capabilities** represent the capabilities of organisations, e.g. their processes and activities. When collective business processes are modelled for a new VO, the VO planner has to search for specific processes or activities that can be performed by single organisations, in order to fulfil the plan.

2. **Capacities** represent free capacities of resources at organizations that are needed to perform one capability. For a VO planning example, specific capacities of organisations are needed to fulfil the required quantitative aspects of capabilities, e.g. the amount of production units per day represents the capacity of production at an organization. If the capacity of one member for a specific capability is not sufficient for a new VBE plan, another member (or a group of members) with the same capability can be also asked to get invited.

3. **Costs** represent the costs of supplying products/services in relation to offered capability and capacity. This information is needed to estimate whether or not inviting a specific group of members to fulfil the VO plan may exceed the planned VO budget.

4. **Conspicuities** represent means for verification of the validity of information provided by the VBE members about their capabilities, capacities and costs. The conspicuities in VBEs mainly include certified or witnessed documents, such as official certifications, licenses, recommendation letters, etc.

An illustration of the generic 4C-model of competency, applicable to all variety of VBEs, is shown in Figure 3.10.

More details about each element in the 4C competency model are provided further in this section. As such, the top-level view on competency is addressed in Section 3.3.2.1, while sections 3.3.2.2 to 3.3.2.5 address the four elements of competency in more detail. For each of these classes, its properties, description, and an example from an educational organisation are provided.

### 3.3.2.1. Competency

As also addressed in previous research (Section 2.2.4.2), the definition of competency cannot be restricted to only a mnemonic competency name, given that it represents a variety of different characteristics. In other words, *competency* represents a container of a number of characteristics. Some of these are primary characteristics. The main characteristic in the competency definition is *Capability*, which refers to a process, task or activity, and defines what an organisation can do.

<table>
<thead>
<tr>
<th>Property name</th>
<th>Specification</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competency ID</td>
<td>Every competency needs to have an identifier that distinguishes it from other competencies. On the one hand, similar competencies (e.g. “teaching” competencies of two different educational organisations) can be distinguished from each other through the set of competency related characteristics (e.g. the teachers at these two organisations have different levels of experience). But on the other</td>
<td>Comp-1, Comp-2, etc.</td>
</tr>
<tr>
<td>Property name</td>
<td>Specification</td>
<td>Example</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Competency name</td>
<td>As addressed above, no single globally agreed textual mnemonic identifier for competency can be defined. Therefore, it makes both the need for and the role played by the “name” for competency doubtful. However, a competency name is needed in order to refer to competencies by human actors. In our approach, such a name is represented by the name of the Competency class, to which a specific competency belongs.</td>
<td>Teaching course of “Databases”</td>
</tr>
<tr>
<td>Competency description</td>
<td>This represents a short textual description/summary of different characteristics of a specific competency. It is needed mainly to give a quick overview of the characteristics to the human actor. The Competency description (together with the Competency class) represents a partial semantic identifier of Competency.</td>
<td>Teaching course of Databases, based on Silberschatz textbook</td>
</tr>
<tr>
<td>Competency class</td>
<td>Competencies within a VBE need to be classified. This facilitates management and navigation of competencies. Since competency represents an assembly of different characteristics, it can be categorised by one of them. In our approach, competencies are classified/categorised by their primary characteristic, namely the Capability. In other words, the Capability classification (as addressed in Section 3.3.2.2) also serves as the Competency classification. As such the Competency class (together with Competency definition) represents a partial semantic identifier of each Competency.</td>
<td>Teaching course of Databases</td>
</tr>
<tr>
<td>Capability</td>
<td>See Section 3.3.2.2.</td>
<td>References to capability Capab-1</td>
</tr>
<tr>
<td>Capacity</td>
<td>See Section 3.3.2.3.</td>
<td>References to capacity Capac-1</td>
</tr>
<tr>
<td>Costs</td>
<td>See Section 3.3.2.4.</td>
<td>References to cost Cost-1</td>
</tr>
<tr>
<td>Conspicuity</td>
<td>See Section 3.3.2.5.</td>
<td>References to conspicuity Cons-1</td>
</tr>
</tbody>
</table>
Large number of different characteristics are associated to competencies of organisations, such as process, resource, product, technique, etc. However these characteristics can be clustered and abstracted, so that only the main/fundamental characteristics can be defined. In our approach, the defined fundamental characteristics such as Capability, Capacity, Costs and Conspicuity. Further details about properties of Competency are defined in Table 3.8.

3.3.2.2. Capability

The capability concept in our approach is mainly rooted in the notion by [55] (see Section 2.2.4.2) who addresses competencies as: *a cross-functional integration and coordination of capabilities*. However, in our approach capability represents a generalisation of the following concepts: “activity”, “process”, “production skill”, “professional situation”, “task”, or “problem”. Basically it defines *what an organisation can do*. Capability represents the fundamental characteristic of competency in our model. Having the “process” as its nature, Capability is defined through its inputs and outputs. The inputs for capabilities represent a variety of resources, while the outputs represent a variety of products. The details about properties of Capability are defined in Table 3.9

Table 3.9: Properties of Capability

<table>
<thead>
<tr>
<th>Property name</th>
<th>Specification</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capability ID</td>
<td>The nature of this identifier is similar to the nature of the Competency ID. Namely, it is presented for use by software actors (e.g. to identify capabilities in databases and software programs).</td>
<td>Capab-1</td>
</tr>
<tr>
<td>Capability name</td>
<td>The nature of Capability name is similar to the nature of Competency name. Thus this name can be completely replaced by the definition of the Capability Class.</td>
<td>Giving lectures on Databases</td>
</tr>
<tr>
<td>Capability description</td>
<td>The Capability description is more extensive than the definition of the Capability class/name and provides a brief summary of other characteristics of Capability.</td>
<td>Giving lectures on Databases based on Silberschatz textbook and slides</td>
</tr>
<tr>
<td>Capability class</td>
<td>This is one of the most important characteristics of Capability, as well as of Competency in general. The Capability class represents the main characteristic that positions an organization in a specific area of activity. As briefly addressed in Section 2.2.4.1, there are some standardised classifications of activities, for example the NACE business area classification [74]. In our approach NACE is taken as the base for the capability classification. Clearly, in order to support specific VBE applications, NACE can be extended with new classes. Furthermore, capabilities can belong to two or more classes from different parts of capability classification.</td>
<td>Giving lectures on Databases (as a subclass of “Teaching” and “Databases”)</td>
</tr>
<tr>
<td>Resource</td>
<td>The resource definition is rooted in the notion of resource by [55] (see Section 2.2.4.2), stating that capabilities represent the organisation’s ability to exploit its resources. Resources are defined through a variety of its attributes, such as class, name, description, amount, etc. However, most resource attributes depend on the class of resource. In resource classification, first resources are divided into four separate classes of “Human resources”, “Physical resources”, “ICT resources”, and “Organisational resources” (e.g. brand, References to resources, e.g. to: • Human resource: teacher • ICT resource: slides by Silberschatz)</td>
<td></td>
</tr>
</tbody>
</table>
Furthermore, for each class, the domain-specific sub-classes can be provided, such as “manufacturing machinery” for the “physical resource” class, etc.

The Product appears as an attribute of competency in [33]. The Product represents both goods and services that belong to the outputs of the processes/activities represented by the member organisations’ capabilities. The main descriptors of product include: name, textual description, class (i.e. of product or service), production strategy (e.g. “engineering to order” for goods and “design of services” for services), and contribution to sales, etc.

<table>
<thead>
<tr>
<th>Property name</th>
<th>Specification</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity ID</td>
<td>This ID is intended for use by software actors (e.g. in identifying capabilities in databases and software programs). Thus, is not mnemonic.</td>
<td>Capac-1</td>
</tr>
<tr>
<td>Capacity description</td>
<td>This characteristic provides explanation of how capacity rates are related to capabilities.</td>
<td>Course is given in fall and spring semesters</td>
</tr>
<tr>
<td>Capacity measure</td>
<td>This characteristic represents a unit of measure for a specific capacity, e.g. “thousands of units per hour”, or “hours per day”.</td>
<td>Two hours of lecture per day</td>
</tr>
<tr>
<td>Capacity rate</td>
<td>This is a specific numeric value for capacity related to its unit of measure.</td>
<td>Two hours of lectures for eight weeks every Monday</td>
</tr>
<tr>
<td>Resource</td>
<td>See Section 3.3.2.2.</td>
<td>References to a resource, e.g.: Teacher</td>
</tr>
</tbody>
</table>

3.3.2.3. Capacity

The need for Capacity is mainly identified through the VBE stakeholders’ requirements. It represents the current availability of resources (i.e. currently free resources) related to what is needed to perform one specific capability. Capacity is a dynamic object that may change regularly, depending on the current workload at the organization and specific events happening in that can affect the lead and/or the management of an organisation. Details about properties of Capacity are shown below in Table 3.10.

3.3.2.4. Cost

This element of competency is identified through the VBE stakeholders’ requirements. Costs represent the costs of providing products/services in relation to a competency. They are needed to estimate whether or not an invitation of a specific group of members for establishing a new VO will not exceed the planned VO budget. The details about properties of Cost are shown in Table 3.11.
Table 3.11: Properties of Cost

<table>
<thead>
<tr>
<th>Property name</th>
<th>Specification</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost ID</td>
<td>This ID is intended for use by software actors (e.g. in identifying capabilities in databases and software programs). Thus, it is not mnemonic.</td>
<td>Cost-1</td>
</tr>
<tr>
<td>Cost description</td>
<td>This characteristic provides an explanation of how capacity rates are related to capabilities.</td>
<td>Cost for teaching a course on Databases</td>
</tr>
<tr>
<td>Cost item</td>
<td>This is an item for which the cost is provided, for example “100 thousands units a day”.</td>
<td>Teaching course on databases, 8 lectures, 2 hours each</td>
</tr>
<tr>
<td>Cost value</td>
<td>This is a monetary price of the Cost item.</td>
<td>XXXXX euro</td>
</tr>
</tbody>
</table>

3.3.2.5. Conspicuity

The conspicuity of the competency information is provided through the evidence documents that are a part of the profile model (Section 3.3.1). This knowledge class is introduced to provide the reason / proof of the validity of the competency information provided by the organisation. A conspicuity can be an on-line document or web accessible information, e.g. an organisation’s brochures, website, etc. Conspicuity documents can also indicate the product quality, financial stability, etc., and they will be kept in the VBE when provided by the VBE entities. The main reason for introducing the conspicuity documents in the VBE is to avoid baseless claims of competencies by organisations. As such, conspicuity can be used to address verification/validation of the competency data. Details about properties of Conspicuity are given in Table 3.12.

Table 3.12: Properties of Conspicuity

<table>
<thead>
<tr>
<th>Property name</th>
<th>Specification</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conspicuity ID</td>
<td>This ID is intended for use by software actors (e.g. in identifying capabilities in databases and software programs). Thus, it is not mnemonic.</td>
<td>Cons-1</td>
</tr>
<tr>
<td>Conspicuity name</td>
<td>This characteristic represents a short name of the conspicuity document.</td>
<td>Confirmation letter from university</td>
</tr>
<tr>
<td>Conspicuity description</td>
<td>This characteristic provides explanation of how the conspicuity document validates competency information.</td>
<td>Document validating teaching capability</td>
</tr>
<tr>
<td>Conspicuity class</td>
<td>The conspicuity of information validity, can be of two different kinds: the “witnessed conspicuity” documents (e.g. a letter of recommendation or an article in a magazine/news section) or the “authorised / certified conspicuity” documents (e.g. accreditation statements, financial ratings, licenses, certificates, patents and awards).</td>
<td>Certified teaching document - BKO</td>
</tr>
<tr>
<td>Document title</td>
<td>This is an original title of a specific conspicuity document.</td>
<td>Confirmation</td>
</tr>
<tr>
<td>Document ID</td>
<td>This is a specific identifier (e.g. license number) of a conspicuity document.</td>
<td>XXXXXXX</td>
</tr>
<tr>
<td>Issuer</td>
<td>This is the name of an organisation, or a person, that issued a specific conspicuity document.</td>
<td>Personnel department of University of Amsterdam</td>
</tr>
<tr>
<td>Validity period</td>
<td>This is a validity period of a conspicuity document.</td>
<td>March 2010 - March 2020</td>
</tr>
</tbody>
</table>
3.3.3. Domain level for profile and competency models

As addressed earlier, further to the elements of the generic profile and competency models that are shared by all VBEs regardless of their domain area application, there are a number of elements that are VBE domain (business area) dependent. Therefore, to address the specificities of profiles and competencies in different VBE domains, the profile and competency models each have the two following levels:

- Core level that represents the generic profile and competency models applied to all VBEs.
- Domain level that represents an extension of the core level with specific components related to each domain or business area of the VBEs. Many domain extensions can be defined for the profile and competency models, depending on the number of different VBE activity/business domains existing in the market and society. All VBEs from the same domain can share the same domain extension. At the domain level, the domain extension is integrated to the object-classes (e.g. Resource Class, Competency Class, Capability Class, etc.) in the generic competency model of the core level (see Figure 3.10). For instance, as illustrated in Figure 3.11, the Capability Class definition of the generic 4C-model at the core level is extended at the domain level with a number of domain specific capability classes (e.g. Metalworking, Product design, etc.). Please note that for the “Capacity” element in the 4C-model, the domain extension is applied to the Capacity Measure element (see Figure 3.10).

Figure 3.11: Domain extension of the 4-C model of competency

This Figure illustrates: A) generalised representation of domain capability extension, namely an abstract example of classification of the capability classes, and B) some exemplified domain capability extensions, namely a real example of the capability classes classification.

Based on the domain classifications introduced in each VBE, the PCMS will organise/collect/group the profile and competency information.

During the creation stage of every VBE’s life cycle [14], the domain level extensions for its profile and competency models shall be created, while during the VBE’s operation and evolution stage, these extensions are usually further evolved.

Development of extensions related to the domain from scratch is very time-consuming. However some software “prototypes” exist for partial extension of ontology related to domains. For example, the activity classifications provided in the NACE codes [74] represent a “prototype” for domain-dependent classifications of the competencies and capabilities that can be used for such extensions at the VBEs.

3.3.4. Aggregate and collective profiles and competencies

It is important and necessary to analyse and address the profile and competency data related to the VBE member organisations at the level of the entire VBE (i.e. to provide a summarisation of all members’ competency information) for several reasons. A main reason is for introducing / advertising the VBE in the market / society (as described in Section 1.3). For this purpose, the VBE needs to show an aggregation of organisations’ profile/competency
information to the market/society, without releasing the names of the individual organisations that provided this information. The second reason for summarisation of profile information, and particularly of the competency information, is for compiling the candidate VO partners’ information during the configuration of new VOs (as also addressed in Section 1.3). The result of such compilation itself forms a new competency that can address specific collaboration opportunities that may arise in the market and/or society. Therefore, new models for summarisation of profiles and competencies need to be developed.

The remaining of this Section gives an example of summarisation of competencies. In order to address the competencies collected in the VBE at the VBE level itself, the two new concepts of “aggregate competency” and “collective competency” are introduced in our approach.

An aggregate competency represents a total aggregation/merge of competency definitions of a number of members, or all members inside a VBE. This aggregation is primarily focused on: (1) evaluation of the ability of a group of VBE members, or of all its members, to address the criteria demanded by a collaborative opportunity, (2) identification of the general competency gaps in the entire VBE in comparison to most COs related to the VBE domain, as well as (3) preparation of the VBE’s aggregate competency catalogue for the VBE customers, as a part of VBE marketing initiatives.

![Figure 3.12: Example VBE structure and competency dissemination in the VBE](image)

Part (A) of this Figure illustrates a sample VBE structure. Namely, the gray circles represent VBE member organisations. The black circles represent a VO. And the gray ring represents a VBE as a whole. In part (B) the Figure illustrates the competency dissemination in the VBE. Namely, the individual competencies are assigned to VBE member organisations. Collective competencies are assigned to VOs. And aggregate competencies are assigned to the VBE as a whole.

Competency aggregation is performed only at the level of “competency instances” (actual existing competencies in the VBE), and not at the level of the “competency model”. The main rules for aggregation of several object-instances (e.g. competency-instances, resource-instances, capability-instances, etc.) are the following:

a. If two or more object-instances belong to the same class (e.g. Competency-Class, Capability-Class, as well as Capacity-Measure), they are merged into one aggregate object-instance. For example, if competencies c1, c2 and c3 (see Figure 3.12) belong to the same “Welding” class (see Figure 3.11), they become one aggregate competency-instance. However, if they belong to different classes, they remain separate instances. If two of them, e.g. c1 and c2, belong to the same Competency-Class, while c3 does not, the c1 and c2 instances become one aggregate competency instance, while the c3 instance remains a separate instance.

b. If the values for the same attribute of two or more aggregated object-instances (see a.
above) are strings, they all become values of the same attribute of the aggregate object-instance. For example, if the competency-instances c1, c2, and c3 are aggregated into one instance, the Competency-Description attribute (see Figure 3.10) of the resulted aggregate competency instance has 3 values that are equal to Competency-Descriptions of c1, c2, and c3.

c. If the values for the same attribute of two or more aggregated object-instances (see a. above) are numeric, they are summarised. For example, the capacity-rate of an aggregation of two capacity-instances is the sum of capacity-rates of these capability-instances.

d. If the values for the same attribute of two or more aggregated competency-instances (see a. above) are objects-instances (e.g. capability-instances), they are processed in the same way as competency-instances (i.e. from a. to e. above). For example, if the competency-instances c1, c2, and c3 are aggregated, the Capability attribute (see Figure 3.10) of the resulting aggregate competency is equal to the aggregation of all capabilities associated with c1, c2, and c3.

A collective competency represents a partial aggregation/merge of competencies of a group of VBE members that constitute the (candidate) partners to form a specific VO. In other words, the collective competency represents a VO Broker’s predefined “competency plan” for VO, that needs to be fulfilled by the selected group of VBE members. The predefined collective competencies are primarily needed in order to (1) get matched against the aggregate competency of the same group of VBE members, (2) calculate the remaining free capacities of each VBE member in addition to those which are currently occupied by its involvement in the VOs, and (3) develop the VO’s profile.

All collective competencies shall be defined through matching of the VO Brokers’ plans, based on COs, during the creation phase of each VO.

3.4. Conclusion

This Chapter introduces the conceptual part of the ColOnto (Collaborative networks Ontology) system addressed in this thesis, namely the design of the unified ontology, called the “VBE-ontology”, which is specified and developed in order to address the VBE’s challenges such as: establishing a common understanding, VBE instantiation in different domains, dynamism and scalability in VBEs, and boosting and balancing the VO involvement. The VBE-ontology offers a formal and comprehensive specification of conceptual VBE knowledge that aims to support both human actors and software components.

This Chapter introduced the methodology developed for construction of the VBE-ontology. It then detailed every step of this methodology: definition of the scope and the design of the VBE-ontology, identification of the techniques for development of the VBE-ontology, etc. Next, we narrowed down on the depth at a specific part of the VBE-ontology devoted to profiles and competencies. This part specifically aims to support the boosting and balancing involvement of VBE members in potential VOs.

The conceptual research results described in this Chapter contribute to the design of the functional part of the ColOnto system, namely the development of ODMS and PCMS systems, addressed in Chapter 4. The ODMS (Ontology Discovery and Management System) consists of functionalities for both VBE-ontology management and VBE-ontology based information management. In turn, the PCMS (Profile and Competency Management System) builds a database, designed to support handling of the profile and competency data within the VBE profile and competency sub-ontologies.
Chapter 4

Functional development of the ColOnto system

Development of ontologies alone is not enough to overcome the challenges of VBE information modelling and management addressed in this thesis. First, development of a user-friendly interface for the VBE-ontology is required to support diverse VBE actors familiarising themselves with the VBE concepts. Second, a set of functionalities are needed to be designed and developed for maintenance of the VBE-ontology and its sub-ontologies. Third, a variety of other ontology-based support functionalities need to be developed and integrated into VBE management, for collection and classification of ontology aspects.

This Chapter addresses both the identification and specification of all this needed functionality for the management of the VBE-ontology. As such, it covers the functional focus of the ColOnto system addressed in the thesis, which is referred to as the Ontology Discovery and Management System (ODMS). Furthermore, the specification of one subsystem of ODMS, called the Profile and Competency Management System (PCMS), is addressed in detail. The PCMS aims at introducing the needed functionality for managing the sub-ontology of the VBE-ontology, related to profile and competency management. The implementation of ODMS and PCMS also serves as the proof of concepts for the conceptual focus of the ColOnto system, as addressed in Chapter 3.

Some parts of this Chapter have been addressed previously in author’s earlier publications, including [49] and [70].

4.1. Introduction

This Chapter addresses the design specification of the functionality required for the Ontology Discovery and Management System (ODMS) and the Profile and Competency Management System (PCMS), thus focused on the functional aspect of the ColOnto system.

Particularly, the ODMS provides software functionalities needed to address the following four specific challenges of the VBE information modelling and management: (i) establishing common understanding, (ii) assisting VBE instantiation in different domains, (iii) supporting dynamism and scalability in VBEs, and (iv) boosting and balancing VO involvement for VBE members. To address the specific challenge of boosting and balancing VO involvement for the VBE members, one sub-ontology of the VBE-ontology is dedicated to specification of the profile and competency of the VBE members (as addressed in Chapter 3, Section 3.3), and one component of the ODMS, namely the PCMS, is designed and developed to support the profile and competency management in VBEs.

This Chapter includes five sections. Section 4.2 describes the approach for design of the ODMS and PCMS. The Chapter addresses the specification, system design and prototype implementation of the ODMS in Section 4.3, while in the Section 4.4 the specification, system design and prototype implementation of the PCMS, are outlined. Section 4.5 concludes this chapter.
4.2. Approach for development of ColOnto’s functional aspects

Design and development process of the ODMS and PCMS systems follow the standard systems development lifecycle as addressed in [80] and therefore consists of seven main steps, including: business analysis, system design, implementation, integration, deployment, operation, and maintenance. Here we first briefly describe these seven steps. The business analysis step focuses on determining and specifying customer requirements. It defines the variety of activities that need to be conducted through the system by its different actors, as well as identification of constraints for the system development. The system design step focuses on description of the structure of the system - architectural design, and its components - detailed design. The architectural design describes the system in terms of its modules. It is concerned with the selection of a solution strategy and the modularisation of the system. The detailed design however develops detailed algorithms and data structures for each module/component. The implementation step involves the coding of the custom-written software and/or the installation of the software purchased. It also involves specification of hardware, database development, program testing and specification of user interfaces. The integration step focuses on incremental integration and deployment of software modules/sub-systems. The deployment step follows a handover of the implemented software to a customer. The operation step represents the changeover from the existing business solution to the new one. And the post-delivery maintenance may represent up to seventy five percent of the lifecycle time of the system.

Due to research mentioned below, our development approach for the functional aspects of ColOnto, described in this chapter, includes only three main steps compared to the seven steps addressed above. In other words, the Maciaszek’s business requirements step for the both systems is not included into this Chapter because it has been addressed earlier in Chapters 1 and 2 of this thesis. Furthermore, for us the Maciaszek’s step of integration is included as a part of implementation. Also, the Maciaszek’s steps of deployment, operation, and maintenance are combined and addressed within one step, because in our research these were all performed within the same sets of trial/take up events.

The three steps of our system design and development are illustrated in Figure 4.1 and first briefly described below, and then in details in the following sections.

1. System design: At this step, we first specify the users of ColOnto and their needs in relation to ODMS and PCMS. We then specify the required functionalities of the ODMS and PCMS. The design of ColOnto’s functionalities specially addresses the research question RQ3 introduced in Chapter 1, Section 1.4 of this thesis. After specification of the required functionalities, we specify the repositories and the database needed for ColOnto, and provide the system design for ODMS and PCMS.

2. Implementation and integration: At this step, ColOnto is implemented through two web-applications, ODMS and one for PCMS, in the Java programming language. Then a set of web-services are developed for integration of the PSMS with the ODMS and for integrating these two systems with other components of the VBE Management System (VMS).

3. Deployment, operation, and maintenance: At this step, ColOnto is deployed at the sites of a number of running 1\textsuperscript{st} generation VBEs in order to perform take up and trial events.
Figure 4.1: Life cycle of development the functional part of ColOnto

This Figure illustrates the four main development steps of the ODMS and the PCMS systems. The input for these steps, as shown in the upper part of the Figure, is represented by: the research motivation for the ODMS/PCMS development (as addressed in Chapter 1), the requirements analysis and the identified related research and development (as addressed in Chapter 2), as well as the specified VBE-ontology (as addressed in Chapter 3).

4.3. Step 1 – System design

This Section addresses our system design for ColOnto. It starts with specification of the needs of VBE users in relation to the ODMS and PCMS, and then addresses the ColOnto functionality. This Section also introduces the design of repositories needed for ColOnto, and the system architecture for the ODMS and PCMS.

4.3.1. Users and their needs

ColOnto facilitates everyday activities of a number of VBE actors (as earlier addressed in Chapter 1, Section 1.2.1.1). The main ColOnto users include VBE administrators, regular VBE members, VO brokers, VO coordinators, as well as VBE experts such as the ontology experts and domain experts.

The functionalities that each of these users needs in the ODMS and PCMS, as well as their responsibilities in relation to these two tools are outlined below in Table 4.1. As such, the specification of these users’ needs and responsibilities also contributes to the specification of ColOnto functionalities addressed in the next Sub-section.
Table 4.1: ColOnto users’ needs and responsibilities in relation to ODMS and PCMS

<table>
<thead>
<tr>
<th>Users</th>
<th>Needs</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In relation to ODMS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VBE administrator</td>
<td>• Introduction of the variety of VBE terminology to new VBE members&lt;br&gt;• Monitoring and evolving VBE databases</td>
<td>• Ensuring correctness, completeness and integrability of the VBE sub-ontologies&lt;br&gt;• Analysing the match between the VBE-ontology and the information in VBE databases</td>
</tr>
<tr>
<td>Regular VBE member, VO Broker, VO Coordinator</td>
<td>• Familiarisation with VBE terminology / concepts</td>
<td>• None</td>
</tr>
<tr>
<td>Ontology expert</td>
<td>• Automation and facilitation of collection and dissemination of terminology / concepts about VBE domain / work area</td>
<td>• Ensuring correctness, completeness and integrability of the VBE sub-ontologies&lt;br&gt;• Discovery of domain information from organisations’ text-corpora</td>
</tr>
<tr>
<td>Domain expert</td>
<td>• Automation of obtaining and analysis of domain-dependent profile and competency data from all VBE members&lt;br&gt;• Automation and facilitation of collection and dissemination of terminology / concepts about VBE domain / work area</td>
<td>Ensuring that domain related data that is uploaded to the PCMS is well structured, complete and correct</td>
</tr>
</tbody>
</table>

| **In relation to PCMS** | | |
| VBE administrator | • Automated obtaining and analysing of profile and competency data, about VBE members<br>• Promoting VBE members in the market/society, through representing their profiles and competencies | • Discovery of new VBE members’ information from their text-corpora<br>• Ensuring that all VBE members submit enough information for their profiles and competencies<br>• Ensuring that the profile/competency information is well structured and complete<br>• Ensuring that all needed competencies are represented in VBEs |
| Regular VBE member | • Automated data submission to the VBE<br>• Familiarisation with the VBE characteristics and potential and with other VBE members | • Provision of complete and up-to-date profile and competency data |
| VO broker | • Retrieval and searching for VBE members’ competencies | • Analysing if the VBE has sufficient competencies (through its members) to produce specific products or services needed by customers |
| VO coordinator | • Retrieving of and searching for VBE members’ profile and competency data, when needed in a running VO | • None |

4.3.2. Identified functionality

We introduce a set of functionalities for ColOnto to assist the main information management processes and operations, which take place through different stages of the entire life-cycle of
a VBE (as earlier addressed in Chapter 1, Section 1.2.1.2). These specifically include three main ontology engineering functionalities that are needed for maintaining the VBE-ontology itself, and five main ontology management functionalities that are needed to support VBE’s information management. Specifications of these functionalities are illustrated in Figure 4.2 and defined below. In this Figure, the PCMS’s functionalities are illustrated as interrelated/integrated with the ODMS’s functionalities. This Figure also indicates how the ColOnto functionalities respond to the four challenges of VBE information modelling and management, introduced in Chapter 1, Section 1.1. More detailed specifications of the prototypically implemented ColOnto functionalities are addressed further in this thesis, in Section 4.4.1.

We have identified eight main functionalities for the ODMS. Among them, three functionalities are aimed to support the maintenance of the sub-ontologies of the VBE-ontologies. The other five functionalities are aimed to support modelling and management of information in VBEs. As addressed in Figure 4.2, four of the eight functionalities are integrated with the PCMS functionalities, namely numbers 3, 6, 7, and 8. Below first the eight ODMS functionalities are introduced and specified, and then the four PCMS functionalities are presented.

---

**Figure 4.2: Main functionalities of ColOnto**

*This Figure illustrates the main functionalities of ColOnto. These consist of three functionalities for maintenance of the VBE-ontology (represented on the upper right side of the Figure) and five functionalities for the VBE-ontology based management of the VBE information (represented at the bottom left side of the Figure). Please note that the ODMS’s functionalities are numbered with Arabic numbers, and the PCMS’s functionalities are numbered with the Roman numbers. The names of the PCMS’s functionalities start with “P&c” that stand for “Profile & competency”. The input-output data streams for every functionality are illustrated by the arrows. The research challenges I to IV, addressed by the functionalities, are located in this Figure in white boxes next to the related functionalities.*
The specification of the ColOnto functionalities particularly responds to the research question RQ3 introduced in Chapter 1, Section 1.4: Which set of functionalities are needed to maintain (e.g. discover, engineer and integrate) the continuously evolving VBE-ontology, as well as the semi-automated management of the information supported through the VBE-ontology?

1. Sub-ontologies registry
We introduce this functionality to support maintaining the sub-ontologies of the VBE-ontology, namely the uploading, registering, organizing, and monitoring of the collection of sub-ontologies within a specific VBE application. It particularly supports grouping and re-organising sub-ontologies for further management, partitioning, integration, mapping and versioning purposes. The main features that we introduce for this functionality include the following:

- **Sub-ontology uploading**: This feature supports uploading sub-ontologies into a specific ODMS application. For each uploaded sub-ontology, the following meta-data should be provided: level of reusability, work area, owner, confidentiality level, points of connection with other sub-ontologies, and version.
- **Registry monitoring**: This feature supports monitoring and analysis of uploaded sub-ontologies. For example, it supports verifying that all uploaded sub-ontologies are well-integrated with each another.
- **Registry modification**: This feature supports making changes in the structure of the sub-ontology registry, for example providing new links between sub-ontologies. These changes are mainly realized through modification of sub-ontology meta-data.
- **External ontology integration**: This feature supports semi-automated integration of existing external domain ontologies (e.g. the ones developed at the site of VBE members) into the VBE-ontology. These are integrated either as parts of existing domain sub-ontologies, or remain separate but interlinked domain sub-ontologies.

2. Concepts learning
We introduce this functionality to support VBE members with their familiarisation with the VBE terminology and concepts. In order to view the terms and their definitions, VBE members first select a specific sub-ontology from the registry. Concepts in the sub-ontologies are represented both in a text format as well as visually through graphs or diagrams. We introduce the following basic features for this functionality:

- **Concept search**: This feature supports search for and displaying of specific concepts from a sub-ontology.
- **Concept viewing**: This feature supports viewing concepts of a selected sub-ontology either in text (i.e. hierarchies) or in graphical format (i.e. graphs and diagrams).
- **Property viewing**: This feature supports displaying definitions, synonyms, abbreviations and other properties of concepts.

3. Sub-ontology modification
We introduce this functionality to support both manual and semi-automated construction and modification of sub-ontologies. Sub-ontologies can be modified within a VBE if the VBE owns them. Development of this functionality aims to assist the VBE administration and domain experts with modification of domain level sub-ontologies collected in the sub-ontology registry. It provides the possibility to directly add new concepts to the sub-ontologies via a GUI and to associate/inter-relate the concepts with each other, by means of up to three predefined kinds of relationships, i.e. through “has subclass”, “has part” and “has attribute” relationships. It also supports annotation of concepts, e.g. submission of synonyms, which are also needed for “concept navigation” and “information discovery” functionalities.
Unlike the user interfaces of most today’s ontology editors, the GUI developed for the VBE-ontology modification functionality must be easily understood and navigated by the VBE members who typically have limited knowledge of ontologies. The main features we introduce for this functionality include:

- **Manual modification**: This feature supports manual creation of new concepts, deletion of concepts and modification of their properties (e.g. definitions, synonyms, etc.) and their inter-relations.
- **Semi-automated concept discovery**: This feature supports semi-automated discovery of appropriate new concepts for VBE sub-ontologies from the text corpora available in the VBE. It is integrated with the ODMS’s functionality of “Information discovery” that is described below under Sub-section 5.
- **Sub-ontology evolution**: This feature supports the user with to semi-automatically analyzing if a sub-ontology needs to be updated. It is based on matching a sub-ontology against its related database. This matching supports the identification of new elements in the databases that are absent from and thus can be also transferred to the sub-ontology. This function is integrated with the ODMS’s functionality of “Repository maintenance”, described below.

4. **Repository maintenance**
We introduce this functionality to support establishment and monitoring of consistency between schemas and content of the databases available in the VBE and their related sub-ontologies. The main features specified to support this functionality include:

- **Repository design**: This feature supports semi-automated development of VBE databases guided by the VBE-ontology. The existing approaches for conversion of sub-ontologies into database schemas (see annex B, Section B.5.4) suggest creation of a map between an ontology and a database schema. This map later supports monitoring the consistency between these ontology and the database schema.
- **System parameterisation**: This feature supports parameterisation of the VMS sub-systems with domain dependent data. It fills in some records in the database from the related to sub-ontologies of the domain level.
- **Repository evolution**: This feature supports indicating inconsistencies between the VBE databases and the VBE-ontology. Specifically, it aims to indicate if the database schemas need to be updated after changes are made in the related sub-ontologies.

5. **Information discovery**
We introduce this functionality to support semi-automated discovery of information from text-corpora, based on the VBE-ontology. The text-corpora used by this functionality can include semi-structured (e.g. HTML-pages) or unstructured sources (e.g. brochures). These are typically provided by VBE member organisations, VBE domain experts, and VBE administration. The main features performed by this functionality include:

- **Text corpora collection**: This feature supports uploading and organising text documents to be used for the discovery process.
- **Thesaurus specification**: This feature supports specification of the concepts in the sub-ontologies of the VBE-ontology to which the information, which needs to be discovered, is related.
- **Concepts identification**: This feature identifies the location of discovered information in the text corpora.

6. **Data navigation**
We introduce this functionality to support the UI functionality for navigation among data records in different VMS tools. Such a support is needed in order to present the variety of data (e.g. profile and competency data) to a user in an easily navigable and digestible format. More
details about it are addressed below for the PCMS’s functionality “Profile and competency data navigation”. The main focus include:

- **Individual object data navigation**: This feature supports displaying data of one individual object, for example one VBE member’s profile.
- **Aggregated data navigation**: This feature supports viewing grouped/summarised data. For example, it represents profile data of several individual member organizations in the same format as data of one organization.

## 7. Data submission

We introduce this functionality to support data submission into VMS tools (e.g. profile and competency data submission into PCMS). It specifically needed when large amounts of heterogeneous data needs to be submitted. More details about it are addressed below for the PCMS’s functionality “Profile and competency data submission”. This functionality supports the following main features:

- **Incremental and semantic data submission**: This feature is helpful when large amounts of data need to be submitted at once into a VMS tool. It also supports submission of data incrementally in a specific predefined order.
- **Gaps analysis and warnings**: This feature supports identifying the information that still needs to be submitted (e.g. a VBE member has to update its competencies or resources information), and sends reminders to VBE members about them. It is integrated with the “Data analysis” feature introduced below.
- **Semi-automated data submission**: This feature is integrated with the “Information discovery” feature addressed above. It supports transferring the data which is discovered from the text corpora into the database.

## 8. Data analysis

We introduce this functionality especially to support specific decision making needed in VMS tools. It is generally based on matching the data in the database against the related sub-ontologies according to some predefined principles in order to make certain specific conclusions. More details about its specific application are addressed below for the PCMS’s functionality “Profile and competency data analysis”.

The PCMS’s functionalities represent specialisation and integration of the ODMS’s functionality in the work area of profiles and competencies management. The four following main specific functionalities are identified for PCMS.

### i. Profile and competency model customisation

We introduce this functionality as an extension of the ODMS’s functionality “Sub-ontology modification”. It aims at customization of the profile and competency sub-ontologies for a specific VBE application. The specific features defined for this functionality include:

- **Profile model navigation**: This function supports navigation in the VBE’s profile / competency models and domain/application extensions.
- **Profile model setting**: This function first supports specifying the profile and competency model of a certain VBE application, by enabling or disabling elements from the sub-ontologies and its domain/application extensions. Second it supports the set-up of access/viewing rights for specific profile elements.

### ii. Profile and competency data navigation

We introduce this functionality to support different ways for retrieval and viewing of the profile and competency knowledge accumulated in the VBE. The navigation scope addresses both: single profile information as well as the collective profile information of the entire VBE. Structuring of the knowledge in the PCMS’s user interface mimics the VBE profile and competency sub-ontology. The profile and competency data on the screen is
displayed in accordance with the related concepts mapped in the profile and competency sub-ontology. The specific functions defined for this functionality include:

- **Viewing single profile**: This function supports viewing and navigation of a specific VBE member organisation’s profile.
- **Viewing aggregate profile**: This function allows data of similar types to be viewed as aggregates (e.g. resources, competencies, etc.) from a group of VBE members. An example of such data collection is a catalogue of aggregate competencies as addressed in the previous Chapter in Section 3.3.4.

### iii. Profile and competency data submission

We introduce this functionality to support uploading the profile and competency knowledge from each member organisation. The incremental submission of data approach is developed for the PCMS. This approach specially supports uploading large amounts of data at once. To support the dynamism and scalability of PCMS, the advanced ODMS’s functionality for “Information discovery” is applied. The specific functions defined for this functionality include:

- **Manual data submission**: For each element in the profile / competency model a data record can be created and later modified/deleted in relation to a specific VBE member organisation.
- **Semi-automated data submission**: This function represents an advanced mechanism incorporated into the PCMS from the ODMS. It supports semi-automated discovery of data for profiles from organisations’ text-corpora.

### iv. Profile and competency data analysis

We introduce this functionality to support the evolution of the VBE’s collection of competencies, as well as to prepare for responding to more opportunities in the market and society. The following features are identified for this functionality:

- **Profile validation**: This feature supports validation and appraisal (e.g. by VBE administration) of the submitted profile data of VBE members.
- **Retrieval and search**: The retrieval function allows retrieval of data for a variety of predefined requests, for example retrieval of a list of all VBE members located in the same city as another VBE member. The search function searches for profiles or profile elements by matching the profile and competency descriptions of a group of VBE member organisations against some specific conditions (e.g. some elements from the descriptions of the new collaborative opportunities that have arisen in the VBE). If there is no “direct” search results related to some specific knowledge classes, “alternative” results from “other” knowledge classes shall be suggested, based on the closeness of knowledge classes in the VBE profile and competency sub-ontology. For example, if no competencies are found for a specific keyword, the search engine will search for resources or practices whose names match this key word.
- **Gap analysis**: This feature identifies missing competencies within the VBE that prevents some collaboration opportunities to be supported by the VBE. This is done by matching the VBE competency catalogue against: (i) the description of the arisen collaborative opportunities, (ii) the past states of the competency catalogues at the times when VBE has the maximal performance, and (iii) predefined competency plan. This function also suggests how to increase competencies within the VBE, for example by getting new human or machinery resources, or by joining resources of several VNE member organizations.
- **Development of new competencies**: This feature supports the creation of new collective competencies (e.g. as addressed in Section 3.3.4) extracted from the existing competencies of VBE members, subsequently offering them as VBE competencies to the market/society.
- **Organisation learning**: This feature supports semi-automated capturing and displaying of the concepts from the VBE-ontology that are related to the area of activities of a specific VBE member.

### 4.3.3. Repositories

For the development of ColOnto we introduce three repositories – (1) a file repository for sub-ontologies, (2) a file repository for text corpora, and (3) a database. These repositories are addressed below.

The two file repositories are managed by the VMS’s bag of assets functionality (as introduced in Section 1.2.1.2).

**1) Repository for sub-ontologies**

This repository represents a flat list of OWL-files together with a registry file. Every OWL-file represents one sub-ontology of the VBE-ontology. The name of the file consists of two parts: (i) a unique ARCON index (as addressed in Annex B, Section 7.1) for this sub-ontology and (ii) a mnemonic name to make it easier for a human actor to identify this sub-ontology.

The *registry file* represents a textual file that gathered the meta-properties of each specific OWL-file, which in turn represent an input for the “Sub-ontologies registry” functionality of ODMS.

**2) Repository for text corpora**

This repository contains the collection of textual files that are collected in order to be processed by the ODMS. These files can be organized in any way that is convenient for the VMS users.

![Database schema for PCMS](image)

*This Figure illustrates the four main tables in the PCMS’s databases. The two tables of “class” and “class relation” correspond to classes and the class relations in the VBE profile and competency sub-ontologies. The two tables of “instance” and “instance_relation” represent the data submitted by VBE member organizations for instances of these classes and class relations.*

**3) Database for profile and competency data**

We designed the PCMS database in order to support its correspondence to the VBE profile and competency sub-ontologies. Namely our PCMS database keeps records for all classes of the profile and competency sub-ontologies that are relevant for the VBE, as well as the relationship among them.
A number of database designs have been considered and evaluated. However, we have rejected the approach where one physical table in the relational database corresponds to one class of the profile data. The main reason for the rejection is the need to support the dynamic creation/deletion of database tables, in other words to meet the requirement for dynamism in profile knowledge classes. Instead, we have chosen an object-oriented design of the database with only one main generic table for all knowledge classes. Thus, all operations with classes simply represent the operation with the records in this table. The final database schema consists of four main tables (as also illustrated in Figure 4.3) including:

- The “class” table for representing the profile and competency classes (from the VBE profile and competency sub-ontologies)
- The “instance” table for representing the profile data instances (i.e. real data from VBE member organizations)
- The “class_relation” table for representing different relationships among the classes
- The “instance_relation” table for representing the relationships among the instances.

4.3.4. System architecture

We have developed the ODMS and PCMS as system components within the package of the prototypical VBE management tools delivered by the ECOLEAD project. There were the following requirements for the implementation design of all ECOLEAD prototypes:

- Independence but integrability of all prototypes. This is the reason why we made the decision to develop ODMS and PCMS as independent Java application, in order to get a full support of Java-based web-services.
- Easy access to the implemented prototypes by end-users and experts. This is why the decision was made to use the client-server architecture with a usual web-browser as a client.
- Using free-ware tools, providing maximum functionalities. This is why the PostgreSQL was chosen as database management system but not the MySQL, since the former supports views and better indexing, which is needed for development of the prototypical VBE management system.

Therefore, we have implemented ODMS and PCMS in Java as two independent web-applications, which are integrated with each other and with other VMS tools through web-services. We have used PostgreSQL for the database. We have implemented the eight earlier mentioned functionalities. The functionalities numbered as 1, 2, 3, 4, and 5 (see Section 4.3.2 and Figure 4.2) are implemented in the ODMS tool. The ODMS’s functionalities numbered as 6, 7, and 8 that have their related PCMS functionalities are implemented as a part of the PCMS tool.

The ODMS’s and PCMS’s system architectures are based on the client-server architecture. This Section first addresses the implementation architecture of the ODMS and then of the PCMS.

ODMS architecture

The ODMS client side represents any web browser that supports sessions. The sessions are used for authorisation. The client side may include a local file repository for handling text corpora (e.g. txt- or html-files) in addition to the ones located on the server (as addressed in Section 4.3.3).

The ODMS server side consists of two main parts, namely (i) the web applications that are implemented in a programming language (e.g. the first ODMS prototype is implemented
in Java) and (ii) the file repository that includes both: the sub-ontologies of the VBE-ontology, as well as the text corpora. The ODMS does not use a database.

The ODMS applications are further logically divided into three main layers as described below.

- **Presentation layer**: This layer represents the ODMS GUI, namely an HTML page, which is the output of running the applications at the ODMS Service layer. For the ODMS GUI, different interfaces are designed and implemented encompassing different rights and roles of ODMS users.

- **Service layer**: This layer includes the applications supporting the ODMS functionalities. For each of the ODMS functionalities there is a Java-servlet that handles the interaction with the ODMS’s GUI. Some of the ODMS functionalities use outputs of web services of other VMS’s sub-systems (e.g. PCMS), if there is a need to access the databases of these tools (see the right-hand side of Figure 4.4).

- **Library layer**: This layer represents a set of libraries (e.g. the first ODMS prototype has a set of Java-libraries) that are used at the ODMS Service layer. It includes two sub-layers, namely the internal library layer and the external library layer. The internal library layer consists of programs (e.g. Java-classes) that are created to handle and support the operations within
the ODMS functionalities. There are three main types of programs in this layer: (1) programs for handling the HTML inputs and outputs, (2) programs for handling the file operations, and (3) programs for handling the outputs of the operations on sub-ontologies. The external library layer represents a set of non-standard libraries that are loaded from several external sources. For example, in order to handle the sub-ontologies in the first ODMS prototype, the Jena-library is used, while in order to handle the text-corpora, the open-source project called HTMLParser is used.

PCMS architecture
The same as the ODMS’s client side, the PCMS’s client side represents the web-browser that supports sessions. The PCMS’s server side consists of two main parts, namely (i) the web applications that are implemented with a programming language (e.g. the first PCMS prototype is implemented in Java), and (ii) the database where the profile and competency data is stored.

![PCMS implementation architecture](image)

*Figure 4.5: PCMS implementation architecture*

This Figure illustrates the PCMS components at the client and server sides, as well as the interaction of the PCMS with the ODMS system. The PCMS client side (on the top of the Figure) represents the web browser that supports sessions. The ODMS server side (on the bottom left-hand side of the Figure) consists of two main parts: (i) the web applications and (ii) the database where the profile and competency data is stored. The PCMS applications are logically divided into the three following main layers: the Presentation layer, the Service layer and the Database layer.

The PCMS application is also logically divided into three further main layers described below:

- **The Presentation layer** of the PCMS consists of one jsp-file and several java classes that together construct the web pages of the PCMS GUI.
• The Service layer consists of the java classes that get the input from the PCMS GUI (through the Presentation layer) and the PCMS database (through the Database layer), performs the operations and returns the output to the GUI / Database. Additionally, this layer includes the authorisation check functions that control the sessions at the PCMS’s client side.

- The Database layer consists of the java-classes that perform the access to the PCMS’s database (as addressed in Section 4.3.3) and manipulates the data.

4.4. Step 2 – Implementation and integration

Based on the system design presented in the previous section, we prototypically implemented ODMS and PCMS. This Section first addresses the implemented ODMS prototype, then the implemented PCMS prototype. After that, it focuses on the web-services that we are implemented to integrate ODMS and PCMS with each other, as well as with other VMS tools.

Figure 4.6: A sample screenshot from the ontology modification functionality

This Figure illustrates one screenshot from the operation of editing meta-data for the example concept “Computer-aided design”. The interface for this operation consists of the following elements (from top to bottom, after class name “Computer-aided design”): properties and description of the concept, fields for editing the label and the comment (i.e. definition) of the concept, and fields for adding and deleting meta-properties of the concept.
4.4.1. ODMS prototype

We have implemented a prototype of the ODMS based on its specification introduced in Section 4.3. In addition to the specified functionalities, we also implemented the authorisation service. It supports secure access to the ODMS by its users. The ODMS prototype supports two main ODMS users, namely the VBE administration and regular VBE members. The implemented prototype functionalities are addressed below in this section.

Sub-ontology registry

The implementation of this functionality in the ODMS prototype represents only an interface for uploading sub-ontologies to the ODMS (as illustrated in Figure 4.7).

Sub-ontology modification

Unlike the user interfaces of most of today’s ontology editors, the GUI of the ontology modification functionality is developed to be easily understood and navigated by VBE members who typically have limited knowledge of ontologies. Figure 4.6 illustrates the screenshot from the operation of editing the meta-data of the “Computer-aided design”. The GUI for this operation provides a few classical forms that are easy to fill in and submit. The representatives from VBE networks who tested the ODMS system found the GUI for ontology editing user-friendly and easy to understand. Please note, the semi-automated concept discovery function of the ontology modification functionality is addressed below, when the information discovery function is addressed.

Figure 4.7: A sample screenshot from the concept navigation functionality

This Figure illustrates the ontology learning functionality representing an ontology viewer, providing an easy-to-understand and user-friendly GUI for searching and viewing concepts from sub-ontologies. This GUI includes four main areas: the concepts catalogue (on the left-hand side), the selected concepts characterisation (on the bottom right-hand corner), the search area (in the middle of the right-hand side) and a pop-up list of available sub-ontologies (on the top right-hand area).
Concept learning

The implementation of the concept learning functionality represents an ontology viewer, providing an easy-to-understand and user-friendly GUI for searching and viewing concepts from sub-ontologies. This GUI includes four main areas (as also illustrated in Figure 4.7): the concepts catalogue (on the left-hand side), the selected concepts characterisation (in the bottom right-hand corner), the search area (in the middle of the right-hand side) and a pop-up list of available sub-ontologies (on the top right-hand area).

In order to solve the problem of visualisation of various relationship types among the concepts (see Chapter 1, Section 1.3.2), the following concept hierarchy structure is introduced. For each concept, all concepts that are related to this concept with the relationships of “has subclass”, “has part”, “has attribute” are grouped through these relationship types, and displayed under the concept. Furthermore, for each relationship type, the quantity of concepts within the group is displayed in brackets/parentheses on the right of the relationship name. For example, in Figure 4.7 the “Associated Partner” class has three properties/attributes, and two subclasses. Additionally, the GUI of the ontology viewing service allows the content of each group to be expanded and collapsed in order to support the navigation. Therefore, the concepts are catalogued not only through their “has subclass” relationships (as is done in many current ontology viewers/editors, such as Protégé [78]), but also through other relationship types, e.g. “has attribute”. Additionally, in order to avoid possible loops in this visualisation interface, a special algorithm is developed that prohibits its formation.

As a result, during the ODMS take-up period, the representatives of current VBE networks related to the ECOLEAD project found both the navigation of the sub-ontologies and the obtaining the specifications and descriptions of different concepts in the ontology easy for the regular VBE members.

Repository maintenance

The implementation of the repository maintenance functionality is specifically aimed at facilitating the Profile and Competency Management System. The PCMS’s database is developed to be mapped with the VBE profile and competency sub-ontologies of the core and domain levels. Therefore the repository maintenance service is needed to preserve the consistency between the database and these sub-ontologies.

The functionality of repository maintenance is performed by matching the classes within the domain level of the VBE profile and competency of every sub-ontology against its corresponding data classes within the domain extensions of the profile model.

Further to preserving consistency, this matching identifies those data classes that are introduced in the domain sub-ontologies, e.g. by the VBE administration, but are missing (do not have any representation) in the PCMS’s database. For example, if some defined competency classes in the sub-ontology are currently missing from the PCMS. In that case a competency gap in the PCMS. is identified. As such, the matching also supports the monitoring and analysis of the PCMS’s database.

Therefore, when a new domain level sub-ontology, which represents the domain parameters for the PCMS, is added to the sub-ontology repository, the Repository evolution functionality identifies the need to expend the PCMS database to include these parameters.
Figure 4.8: A sample screenshot from the repository maintenance functionality. This Figure addresses a sample screenshot showing the result of matching the domain level process sub-ontology against the related PCMS data classes. As regards the two column table in the middle of the Figure, left column shows the data classes from the ontology that need to be added to the database, while the right column shows the data classes that exist in the database and need to be added to the ontology.

Figure 4.9: A screenshot from the Information discovery functionality. This Figure shows a sample screenshot from the GUI of the ODMS’s discovery service. This GUI includes three main areas: (1) the area for selecting/uploading the text-corpora and thesaurus (on the upper right-hand side), (2) the text-corpora, within which the results of discovery are highlighted (on the left-hand side), and (3) the selected/applied thesaurus catalogue (on the lower right-hand side).
On the other hand, matching also identifies those data classes that are introduced by users in the PCMS’s database (e.g. as competencies), while they are not yet presented within the domain sub-ontologies. Thus, identifying the need to extend the domain sub-ontologies, which represents the sub-ontology evolution function of the ontology modification functionality.

Figure 4.10: Sample text-corpora provided by a VBE member to the ODMS
This Figure illustrates a sample of a web page used for ODMS’s information discovery. This page includes the core terms (e.g. “products”, “services”, etc.) and domain terms (“Metallic Pieces”, “Pulley”, etc.) that are relevant to the core and domain levels of the VBE-ontology, and thus can easily be discovered and transferred to the databases of the VBE Management Sub-systems.

To obtain a list of classes from the PCMS database, the repository maintenance service uses the output generated by a web service developed within the PCMS.

A sample screenshot showing how the domain level process sub-ontology is matched against the related PCMS data classes is given in Figure 4.8.

During the take-up period of the ODMS and PCMS systems, the VBE representatives were using the evolve service to monitor the consistency between the PCMS database and the VBE profile and competency sub-ontology, and found it informative and easy to use.
Information discovery

The implementation of the information discovery service is based on the approach for concept discovery from text corpora as presented in [25]. For our purposes, this approach is extended with specific VBE features, for example the use of the VBE-ontology for formation of the thesaurus.

The GUI for the discovery service is illustrated in Figure 4.9. It includes three main areas: (1) the area for selecting/uploading the text-corpora and the thesaurus (on the upper right-hand side), (2) the text-corpora, where the results of discovery are highlighted (on the left-hand side), and (3) the selected/applied thesaurus catalogue (on the lower right-hand side). This implementation also facilitates the transferring of the newly discovered concepts, e.g. a new by disconnected VBE competency, into sub-ontologies of the VBE-ontology. Namely, Figure 4.9 illustrates that the system has located 3 concepts in the text-corpora, i.e. mission, competency, and capability. Two of these concepts exist in the VBE-ontology, but one of them, i.e. process, is in fact a synonym of an existing concept. Therefore, capturing the semantics in the VBE-ontology supports obtaining more information from the text-corpora.

The representatives of the running networks performed the discovery of information in order to expand the profiles of the VBE members, as collected by the Profile and Competency Management System. They provided the text corpora consisting of the web pages of their VBE member organisations that were uploaded into the ODMS. A sample web page used during the discovery is shown in Figure 4.10. These VBE network representatives then also selected some of the concepts from the core level profile and competency sub-ontology and formed the thesaurus. The thesaurus consisted not only of the selected terms, but also of their synonyms and abbreviations. Next, the Information discovery functionality located the phrases in the text-corpora that were related to the concepts from the thesaurus, e.g. “Finishing process” related to the “Capability” concept. In the last step, this identified information was added to the members’ profiles inside the PCMS.

Furthermore, some of the located terms represented the concepts (e.g. “Finishing process”) that could be added to the domain level profile and competency sub-ontologies. These were then added to their related sub-ontologies thus supporting the Semi-automated concept discovery function and the Sub-ontology modification functionality.

4.4.2. PCMS prototype

To test the effectiveness of the development of PCMS for responding to the challenge of boosting VO configuration, a first prototype of the PCMS is implemented.

A challenge for the PCMS implementation was to design how to represent both the profile and competency model and data on the screen. Suitable friendly graphical user interface of the profile and competency knowledge is required to support the VBE user community navigation, understanding and “digestion” of the concepts as well as how to use the system. For ontologies, the more complex the knowledge, the more difficult it is to specify its proper visualization. Below we introduce the “catalogue” forms we have designed for the profile knowledge visualisation. Each catalogue mimics the visualisation of an acyclic graph including both the knowledge “classes” (representing both: core classes and domain classes) and their “instances” represented as “nodes” in the graph, and including three types of relationships as its “edges”. These relationships include: (1) the generalisation relationship (called “has subclass”) defining classes and their subclasses, (2) the aggregation relationship
(called “has attribute”) defining classes and their attributes, and (3) the instantiation relationship defining classes and their instances.

Figure 4.11: A sample illustration of PCMS’s class catalogue

This Figure illustrates the PCMS’s class catalogue. All entities in this catalogue represent knowledge classes from VBE profile and competency sub-ontology. The image located next to a class indicates that this class is a sub-class of its upper-level class. The absence of this image next to a class indicates that this class is an attribute of its upper-level class. The smaller-font entries next to the class entries, e.g. “14 attributes” or “2 subclasses” represent a summary of the class definitions. The clickable □ and □ images expand and collapse the catalogue items. A □ radio-button next to each entry supports the selection of an entry to perform some operations on it, e.g. for creation of a new subclass or a new attribute.

Two types of catalogues, namely the **class catalogue** and the **instance catalogue**, that are designed for representing the VBE member organisations’ profile and competency knowledge, are illustrated in Figures 4.11 and 4.12 and described below.

The PCMS’s **class catalogue** represents an acyclic graph including the profile knowledge classes as the nodes, and the relationships among these classes as the edges. The relationships among the classes represent two types of: “has attribute” relationships (e.g. a competency definition has a capability definition as an attribute) and the “has subclass” relationships (e.g. the manufacturing capability has the welding capability as a subclass).

Below Figure 4.11 illustrates the list of the top-level classes of profile knowledge, such as the “General data”, “Contact data”, “Resource”, etc. The representation of two classes, namely the “General data” class and the “Resource” class are also expanded, so that the fourteen attributes of the “General data” class, as well as one attribute and four sub-classes of the “Resource” class can be illustrated.
Figure 4.12: A sample illustration of PCMS’s instance catalogue

This Figure illustrates the PCMS’s instance catalogue. The same as for the class catalogue illustrated in Figure 4.11, the bold entries represent knowledge classes. But further to that, the image in this catalogue indicates a record, e.g. for contact data. Another difference with the class catalogue is that a radio-button next to each entry supports the selection of an entry to perform some operations on it, e.g. creation of a new instance for a class.

The PCMS’s instance catalogue represents an acyclic graph that includes the profile knowledge classes together with their profile knowledge instances, as the nodes, and the relationships among these classes and instances as the edges. The relationships among classes in this catalogue represent only the “has subclass” type, and the instances are not connected among each other directly - while the main types of the relationships in this model represent the relationships between classes and their instances. A sample illustration of the instance catalogue is addressed in Figure 4.12. This Figure illustrates a list of classes for the profile knowledge, and some existing records for these classes are also presented from one VBE member organisation in Swiss Microtech (SMT), which is a metalworking VBE in Switzerland. In this Figure, the record for “General data” is expanded so that the records for its attributes can be viewed. For example, the record for the “Creation date” is “1956”. The Figure also illustrates that the abstract “Resource” class has no direct instances/records; it has these only through its sub-classes, e.g. the “Human resource” class has records/instances.

The GUI of the four implemented PCMS’s functionalities are based on the two above catalogues of class and instance. The PCMS functionalities of model customisation, data submission, data navigation, and data analysis are further described below in this section.

Model customisation

The customisation functionality enables modification of the VBE profile model through creating, copying, deleting and updating profile data classes, which are stored in the PCMS database. The profile model in fact represents the VBE profile and competency sub-ontology converted to the database format. This functionality has two different interfaces, namely for (1) navigation in the catalogue of profile classes, i.e. profile model, (2) operation on a specific part of the class catalogue.
The VBE profile model can be viewed and modelled through a catalogue of profile data classes (as shown in Figure 4.13). The items in this catalogue include only the profile element classes (represented in bold). These classes are connected among one another by two types of relationships: “has subclass” (indicated by a hexagon icon) and “has part” (not indicated by any pictogram). Operations to create, delete and modify classes are carried out using the buttons on top.

Figure 4.13: PCMS’s catalogue of profile data classes for SMT, a VBE in Switzerland
This Figure illustrates the viewing and navigation in the VBE profile model which is carried out through a catalogue of profile data classes in the PCMS. The items in this catalogue include only the profile element classes (in black). These classes are connected among one another by two types of relationships: “has subclass” (indicated by a hexagon icon) and “has part” (not indicated by any icon).

Data submission
The submission functionality supports uploading and editing of its own profile data by a specific VBE member through creating, copying, deleting and updating profile data records. This functionality has two different interfaces, namely for: (1) navigation in the profile data, (2) operation on a specific part of the profile.

Each profile may be viewed and navigated through a catalogue of profile data (as illustrated in Figure 4.14 for VBE member “ADAX”). The items in this catalogue include both the profile element classes (in bold) and the records of real profile data (highlighted). These are separated from each other with the “>” sign. Operations to enter, delete or modify the profile data are carried out using the buttons on top.

The ODMS’s functionality for Discovering information enables discovery of profile and competency data from organisations’ text-corpora. The interface for this discovery is implemented within the ODMS and described in Section 4.4.1.
Figure 4.14: PCMS’s service for editing profiles for SMT, a VBE in Switzerland
This Figure illustrates navigation and viewing of a specific member’s profile which is carried out through a catalogue of profile data. The items in this catalogue include both the profile element classes (in bold) and the records of real profile data (highlighted).

Data navigation
The navigation functionality displays the profile and competency data collected through the entire VBE in the form of catalogues. This functionality has four different interfaces for navigation of: (1) the catalogue of profiles, (2) the single profile, (3) the catalogue of individual competencies, and (4) the catalogue of aggregate competencies.

The “catalogue of profiles” enables the catalogue of all registered VBE members whose profiles are represented in the PCMS. Each profile in the catalogue can be selected for more detailed viewing. The single profile’s interface is similar to the one from the profile editing service. The “catalogue of unique competencies” allows the catalogue of all competencies submitted in the PCMS to be viewed. The owners of the competencies are indicated in front of each competency’s name. The “catalogue of aggregate competencies” (as partially illustrated in Figure 4.15) enables the catalogue of aggregate competencies submitted to the PCMS to be viewed. The algorithm for aggregation of competencies is described earlier in this thesis in Section 3.3.4. The owners of every aggregate competency are indicated in front of this competency’s name.

Data analysis
The analysis functionality (see Figure 4.16) facilitates decision making about profile and competency data that are accumulated in the VBE, namely its supports the functions of validation/appraisal of members’ competencies, gap analysis in VBEs and identification of the need for new competencies’ development. In the current version of the PCMS development, this functionality is based on the search for profile and competency data. This search consists of three steps, as also indicated as operations with buttons on the top of the window: (Step 1) Selecting search fields from the catalogue of the profile element classes,
(Step 2) Specifying the search criteria (in the search criteria form) and activating the search, and (Step 3) Viewing the results of the search and moving to the profile of a specific VBE member which was identified during this search. At the last step, in order to indicate how well a specific VBE member matches the search criteria, the list of all VBE member’s profile data records that match the criteria are displayed below the name of each VBE member. In case there is no “direct” search results for some specific required conditions, “alternative” results are suggested automatically by the data analysis functionality, based on the closeness of the required conditions to the existing data from the members’ profiles.

Figure 4.15: Viewing aggregate competencies in the PCMS for SMT, a VBE in Switzerland

This Figure shows the “catalogue of aggregate competencies” that enables all the competencies submitted in the PCMS to be viewed in an aggregate form. The list of individual owners belonging to every aggregate competency is indicated in front of the competency name.

4.4.3. Integration within VMS

The ODMS supports several VMS sub-systems, e.g. Trust Management System, Collaborative Opportunities Finder, VO Information Management System, etc., in the same way in which it supports the PCMS. Integration of ODMS and PCMS in our implementation is realised through a web-service developed on the PCMS side. In addition to interaction with ODMS, the PCMS also interacts with other VMS sub-systems that support the VO creation, namely with the tools for: collaborative opportunity finding and decomposition, VO rough planning, and VO partners service and suggestion (as introduced in Chapter 1, Section 1.2.1.2). Namely, it provides these tools with up-to-date profile and competency model, as well as information about the VBE and its member organizations gathered as the PCMS’s profile and competency data. The following two specific web services are developed:
Figure 4.16: Search for competencies in the PCMS for SMT, a VBE in Switzerland

This Figure illustrates Step 3 of the function for searching profile and competency data. Namely it illustrates that 7 member organisations have the “milling” or “drilling” (which were specified criteria in Step 1 and 2) in their competency descriptions.

- **Web service to interact with ODMS.** This web service is developed in order to enable matching the ODMS’s VBE profile and competency sub-ontology against the profile element classes in the PCMS’s database. It supports the ODMS’s functionality of “Repository maintenance”.

- **Web service to interact with VO creation tools.** This web-service provides the VO creation tools with PCMS’s profile and competency model, as well as with the PCMS’s data. Within this web-service, two web-methods are developed. The first web-method generates and provides the PCMS’s profile and competency model in the XSD schema format. The second web-method generates and provides an extract from the PCMS’s profile and competency data in the XML schema format. As an example, a part of the XML output for a running VBE called IECOS (from Mexico) is illustrated in Figure 4.17.

## 4.5. Step 3 - Deployment, operation and maintenance

After the prototypes of the ODMS and PCMS were developed, they were taken up within the ECOLEAD project by four running VBEs, namely: IECOS in Mexico, CeBeNetwork in Germany, HELICE in Spain, and Swiss Microtech in Switzerland (see annex A for descriptions of these networks).

The ODMS prototype was deployed on a server as one copy and was accessed by a number of VBEs. Individual access rights were provided to every VBE. Unlike ODMS, five
copies of the PCMS prototype (one for every VBE plus one joint trial PCMS for CeBeNetwork and HELICE) were deployed also on the same server. During the period of six months, we conducted the maintenance of these developments on the server and ensured that the deployed applications were always available and supporting local needs.

At this time, the representatives of the four VBEs were configuring their PCMS profile and competency model and uploading their PCMS with profiles of their member organizations. They also used and accessed all functionalities of the PCMS and ODMS.

Some improvement and extension of the PCMS and ODMS also took place during their take-up period. After the take-up sessions, the four networks evaluate the ODMS and PCMS. The objectives and results of this evaluation are addressed in more details in Chapter 5, Section 5.3.1.

- `<p>VBE_entity>`
  - `<p>General_data>`
    - `<p>Legal_Name>` IFACSA `<p>Legal_Name>`
    - `<p>Legal_Status>` Anonymous Society of Variable Capital `<p>Legal_Status>`
  - `<p>General_Description>`
    - Manufacturing services company with several years of experiences in automotive industry `<p>General_Description>`
    - `<p>Creation_Date>` 2003 `<p>Creation_Date>`
    - `<p>Application Area_Sector_Domain>` Metalworking `<p>Application Area_Sector_Domain>`
    - `<p>Size_No_of_Employees>` none `<p>Size_No_of_Employees>`
  - `<p>Mission>`
    - To be a company dedicated to the machining and stamping of high quality manufacturing pieces, in
    - where the human resources have as main objectives to offer quality, punctuality and service to the
    - clients `<p>Mission>`

Figure 4.17: XML output of the PCMS’s web service for IECOS, a VBE in Mexico

This Figure illustrates a profile of a VBE member organisation in an XML format. It is
generated by a PCMS web service, in order to transfer the profile data from PCMS to
other VMS tools.

### 4.6. Conclusions

This Chapter addresses identification and specification of the functionality needed for ColOnto, which also represents the response to research question RQ3 introduced in this thesis: Which set of functionalities are needed to maintain (e.g. discover, engineer and integrate) the continuously evolving VBE-ontology, as well as the semi-automated management needed of the information supported through the VBE-ontology? Particularly this Chapter introduces two software application: Ontology Discovery and Management System (ODMS) and Profile and Competency Management System (PCMS). The ODMS provides eight specific functionalities divided into two main groups: (1) three functionalities for maintenance of the VBE ontology and (2) five functionalities for VBE-ontology based information management in VBEs. The PCMS provides five main functionalities, which represent a result of applying the ODMS for the work area of VBE profile and competencies. The ODMS and PCMS are designed as two independent while integrated software applications. The system design for the two of them is addressed in Section 4.3. We have also prototypically implemented both PCMS and ODMS. The prototypes together with a large number of example screen-shots are presented in Section 4.4.
Chapter 5

Conclusion, validation and future work

5.1. Introduction

This Chapter summarises the research results and concludes this thesis. First, it provides a summary of our achievements in relation to the research questions and research objectives specified in Chapter 1. The specific chapters and sections of this thesis addressing these achievements are outlined. The Chapter then evaluates and validates the research results. To validate the results, a number of approaches are used. Finally, this Chapter describes lessons learned in conducting this research, and presents some ideas for further research.

Achieved conceptual objectives

**RO1**: Design and development of the VBE-ontology

- Definition of the scope of the VBE-ontology
  - Figures 3.2 and 3.3

- Specification of the design of the VBE-ontology
  - Figure 3.4

- Building up of the first version of the VBE-ontology
  - Figure 3.8

Achieved functional objectives

**RO2**: Design and development of the profile and competency models

- Detailed specification of the profile model and the 4C-model of competency within the VBE-ontology
  - Figure 3.9

Achieved functional objectives

**RO3**: Development of Ontology Discovery and Management System

- Specification and development of functionalities to support: establishing common understanding of VBE aspects, VBE instantiation in different domains, and dynamism and scalability in VBEs

- Implementing a prototype of ODMS
  - Figure 4.2

- Figure 3.10

**RO4**: Development of Profile and Competency Management System

- Specification and development of functionalities to support balancing and boosting partners’ VO involvement within the VBEs

- Implementing a prototype of PCMS
  - Figure 4.7

- Figure 4.13

Figure 5.1: Justification for achievement of research objectives

This Figure illustrates the main research and development results achieved for addressing the four research objectives set in this thesis. Namely for every objective it shows the main diagrams and Figures addressed in chapters 3 and 4, for illustrations of the design, development, and implementation performed for this thesis. This Figure also illustrates which research and development results address which research questions: RQ1, RQ2, and RQ3, targeted in this thesis.

5.2. Reflection on research and development results

This Section briefly summarises and justifies our achievements in relation to the four introduced research objectives, a number of raised problem areas, and the specified research questions that we specified for this thesis, as presented in Chapter 1, Section 1.4.

121
5.2.1. Addressing research objectives

In this thesis, we have set four research objectives, which together aim at building up the VBE-ontology and the ColOnto system supporting several specific challenges related to the VBE management system. The achievements of our research towards these research objectives are addressed and justified below, as well as illustrated in Figure 5.1.

1. **RO1: Design and development of the VBE-ontology**
   - **Definition of the scope of the VBE-ontology:** The scope for the VBE-ontology is specified in Chapter 3, Section 3.2.3 through grouping of all possible VBE-ontology concepts into two “horizontal” levels of reusability, and ten “vertical” work areas. The “core level” of reusability includes the concepts that are common for VBEs from all application domain. The “domain level” of reusability includes domain-specific concepts. Every work area represents a group of concepts that are needed for one specific VBE management tool.
   - **Specification of the design of the VBE-ontology:** The design of the VBE-ontology is specified in Chapter 3, Section 3.2.4.1. It represents the VBE-ontology consisting of a number of partitions called “sub-ontologies”. These sub-ontologies are individual but interconnected ontologies that are used separately in specific VBE management tools of a specific VBE application domains.
   - **Building up of the first version of the VBE-ontology:** This first version is built up as addressed in annexes D and E. This version consist of all sub-ontologies of the core level and a subset of sub-ontologies of the domain level.

2. **RO2: Design and development of profile and competency models**
   - **Detailed specification of the profile and competency models within the VBE-ontology:** The detailed specification of the VBE member’s profile and the VBE member’s competency are addressed in Chapter 3, sections 3.3.1 and 3.3.2. Specifically the competency is addressed as a combination of member’s capability, capacity, conspicuity, and costs, as designed in the 4C-model.

3. **RO3: Development of Ontology Discovery and Management System**
   - **Specification and development of functionalities to support:** establishing common understanding of VBE aspects, VBE instantiation in different domains, and dynamism and scalability in VBEs. The ODMS is specified and developed, as addressed in Chapter 4, sections 4.4.1 and 4.4.2. To address the above three challenges, the ODMS provides functionalities for: VBE sub-ontologies integration, VBE-ontology learning, ontology-based database design and development, and ontology-based information discovery from text-corpora.
   - **Implementing a prototype of ODMS:** A prototype of the ODMS is developed in Java, as addressed in Chapter 4, Section 4.4.3.

4. **RO4: Development of Profile and Competency management System**
   - **Specification and development of functionalities to support balancing and boosting partners’ VO involvement within the VBEs:** The specification and development of the PCMS is addressed in Chapter 4, sections 4.5.1 and 4.5.2. In order to support the above challenge, the PCMS is based on a core sub-ontology for VBE member’s profiles and competency, as well as incorporating the domain level sub-ontologies for profiles and competencies to support VBE members with defining their own competencies.
   - **Implementing a prototype of the PCMS:** A prototype of PCMS is implemented in Java, as addressed in Chapter 4, Section 4.5.3.
5.2.2. Addressing the identified problem areas

As a part of addressing the four research objectives, we have also addressed the identified research problem areas, as presented in Section 1.3.2, namely:

5. **In relation to VBE-ontology and the ODMS**
   - **Systematic design and development of the VBE-ontology:** In order to develop the VBE-ontology, we applied the methodology introduced in Chapter 3, Section 3.2.
   - **Maintenance and evolution functionalities for VBE-ontology:** We have developed both the maintenance and management functionalities for the VBE-ontology within the ODMS system, as addressed in Chapter 4, Section 4.3.
   - **VBE ontology-based management functionalities:** We have developed a number of VBE-ontology-based management functionalities within the ODMS system, for example for competency data discovery from textual documents, as addressed in Section 4.4.1.1.
   - **Ontology visualisation:** We have developed a user-friendly interface to facilitate familiarising VBE members with the VBE-ontology, as addressed in Chapter 4, Section 4.4.3.

6. **In relation to profiles & competencies and the PCMS**
   - **Establishing unified/generic models:** We have developed models for VBE members’ profiles and competencies, which are reusable by all VBEs and all kinds of members, as addressed in Chapter 3, sections 3.3.1 and 3.3.2.
   - **Continuous update of profile data:** Our developed PCMS supports incremental submission of dynamically changing capacities of companies, which is an important challenge in VBEs, as addressed in Section 4.5.1.1.
   - **Handling the confidentiality of profile data:** A system for access rights is developed addressing all elements of profiles and competencies, as addressed in Chapter 3, Section 3.3.1.
   - **Maintenance and management of VBE profiles:** Our PSMS provides a variety of functionalities for maintenance and management of VBE members’ profiles, as addressed in Section 4.5.1.1.
   - **Generic competency naming:** In Section 3.3.2.1 we have concluded that specifying only a mnemonic name (for example “metalworking”) does not properly serves as an identifier for a competency, rather a special identifier shall be constructed for identifying competencies that is also usable by software tools. When referred to by people, the main competency characteristics such as organization’s capabilities, capacities, conspicuities, and costs shall be mentioned in addition to the competency name (for example metalworking using computer aided development).
   - **Cataloguing competencies:** Adapting the domain level sub-ontologies for profiles and competencies in PCMS makes it possible to uniformly catalogue competencies, as addressed in Section 4.5.1.1.

5.2.3. Addressing research questions

In this thesis we have addressed the three research questions set introduced Chapter 1, Section 1.4 in the following way:

**RQ1. Can we identify the scope and the elements of ontology encompassing the wide variety of VBE related entities and concepts so that it represents the diversity of its subspaces, addressing all endogenous elements and exogenous interactions, and specifically the subspace of profile and competency management?** The response is positive,
and we have achieved it as follows. Considering a large variety of heterogeneous types of concepts accumulated in the VBE environments, specifying the scope of the VBE-ontology was a challenging task. A systematic approach is developed and applied for the whole process of the VBE-ontology development, where scope specification is one of the early steps. Firstly, the purpose for VBE-ontology development is clarified and specified in detail. Then, based on this purpose specification (Section 3.2.1), VBE stakeholders’ requirements (Section 2.4.2), and the ARCON reference model of VBEs (Section 1.2.1), an approach for defining the VBE-ontology scope was developed as described in Section 3.2.3. To define the scope, we split the whole possible VBE concepts into groups by two main characteristics of: (1) reusability by different VBE applications (i.e. into the core / domain independent as well as domain dependent concepts), and (2) reusability in different work areas (i.e. into groups of concepts used within different VBE management functionalities).

RQ2. Can we capture, organise and specify the large set of diverse but interrelated aspects identified in RQ1 in the VBE-ontology, considering both their evolutionary nature and the heterogeneity of their sources? The response is positive, and we have achieved it as follows. Deciding on the physical construction of the VBE-ontology was the next challenging task of the VBE-ontology development approach. To address it, we went further with our idea of grouping VBE concepts basically, applying the divide and conquer principle. Considering the variety in the nature of different groups of VBE concepts, the physical structure of the VBE-ontology is defined as a set of independent but complementary “sub-ontologies”, each of them representing the result of intersection of two concept-reusability levels and ten work areas. Having a set of sub-ontologies facilitates their “digestion” by human VBE actors, and supports their independent reuse within a different sub-system of the VBE management system.

RQ3. Which set of functionalities are needed to maintain (e.g. discover, engineer and integrate) the continuously evolving VBE-ontology, as well as the semi-automated management needed of the information supported through the VBE-ontology? In order to address this research question, a state-of-the-art study on ontology engineering and management is conducted (sections 2.2.3 and D.4). Furthermore, in order to develop specific approaches for management of VBE profiles and competencies, a state-of-the-art study on profile and competency management as addressed in different sciences is conducted. Based on the purpose of management of the VBE-ontology, as well as on the state-of-the-art findings, two sets of functionalities are specified. Section 4.4 defines the functionalities for the Ontology Discovery and Management System (ODMS), including a number of functionalities for maintaining the sub-ontologies of the VBE-ontology, and a number of functionalities for ontology-based management of information. Section 4.5 addresses functionality for the Profile and Competency Management System (PCMS), including functionalities for adaptation of the profile and competency sub-ontology, and functionalities for ontology-based management of profile and competency data.

5.3. Evaluation and validation of research results

Considering the nature of our research results, we specified a method for their evaluation and validation, which is based on the approaches suggested in [52] and [81]. The first one addresses evaluation/validation of ontologies, while the second one addresses evaluation/validation of software systems. We apply the synergy of these two approaches to evaluate/validate both the conceptual and functional parts of the ColOnto.

The approach by [52] suggests validation against collected requirements. Therefore, our research results are validated against the requirements that we specified within our requirements analysis covered in Section 2.4. In turn, the evaluation/validation approach by [81] addresses four techniques, namely case study, feature analysis, survey, and formal
Out of these four, we have chosen the following two techniques as more suitable for evaluation/ validation of ColOnto: *Case study* – which depicts a holistic portrayal of a client’s experiences and results regarding a system. A case (under study) can be related to individuals, programs or any unit, depending on what the program evaluators want to examine through in-depth analysis and comparison. *Feature analysis* – which is primarily used to rate and rank attributes of a developed software product, in order to evaluate whether it is innovative on the basis of specific standards or against other products.

Based on the above evaluation techniques, and considering the specificities of our research findings, we developed and applied the following three main methods for evaluation and validation of ColOnto are:

1. **Evaluation through case study of end-users’ experiences.** This approach aims an empirical evaluation of the ColOnto by the end-users, namely representatives of running VBEs. The ODMS and PCMS tools were taken up in practice by four existing VBEs. After a short training period, the VBE representatives performed a predefined set of their daily operations using our tools. Their opinions were then collected regarding the performance of the ODMS and the PCMS in comparison to their standard tools/practices in performing these activities. For representing the evaluation results, participants filled in evaluation questionnaires addressed in annex C, Section C3. This comparison is done using a number of standard software quality requirements, collected in Section 2.4.1.2. The empirical validation results are presented in Section 5.3.1.

2. **Self-validation through feature analysis against other existing models and systems:** In addition to performing the empirical evaluation, another approach is developed that verifies whether the research results addressed in this thesis (namely, the VBE-ontology, the 4C-model of competency, the ODMS, and the PCMS) respond to requirements specified for them in Chapter 2, Section 2.4. In this approach, the research results are also compared against other existing models, approaches and tools developed for similar purposes the results of this validation process is presented in Section 5.3.2.

3. **Peer-reviewed validation within the scientific community:** Besides the two above approaches based on [52] and [81], we also consulted with other experts in the area of information modelling and management for Collaborative Networks, to collect their suggestions and comments for the purpose of validating our results. This peer validation process heavily focused on presenting and publishing our research findings in scientific internationally accepted channels in related areas, and its results are outlined in Section 5.3.3.

The results of these evaluations and validations demonstrate that the ColOnto solution responds well to the purpose for its development, providing efficient approaches for bringing the running VBEs to their 2nd generation, while also being supported by the international academic community.

**5.3.1. Evaluation through case study of end-users’ experiences**

As addressed earlier in sections 4.4.4 and 4.5.4, the prototypes of the functional part of the implemented ColOnto system (i.e. ODMS and PCMS tools) was taken up and evaluated by four manufacturing VBEs: Swiss Microtech (SMT), CeBeNetwork (CBN), HELICE and IECOS (as addressed in annex A). This evaluation was performed using the “Q-c1” and “Q-c2” questionnaires as described in annex C, Section C.3
To evaluate the ColOnto, the following standard indicators/criteria are used: *efficiency, reliability, usability* and *correctness* (as described in Section 2.4.1.2). In addition to these four criteria, a fifth criterion, *innovativeness*, is also used. A range of values is assigned to these criteria as addressed in Table 5.1. These values indicate whether the performance of the ODMS/PCMS was good, satisfactory or unsatisfactory during the take-up period. The results of this validation are addressed below separately for ODMS and PCMS.

Table 5.1: Legend used for assignment of values to the evaluation criteria (for ODMS and PCMS)

<table>
<thead>
<tr>
<th>Qualitative indicator/Value</th>
<th>0 (unsatisfactory)</th>
<th>1 (satisfactory)</th>
<th>2 (excellent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency (consumption of resources)</td>
<td>20% increase</td>
<td>15% decrease</td>
<td>50% decrease</td>
</tr>
<tr>
<td>Efficiency (consumption of time)</td>
<td>20% increase</td>
<td>15% decrease</td>
<td>50% decrease</td>
</tr>
<tr>
<td>Reliability</td>
<td>Low</td>
<td>Satisfactory</td>
<td>High</td>
</tr>
<tr>
<td>Usability</td>
<td>Difficult</td>
<td>Satisfactory</td>
<td>Easy</td>
</tr>
<tr>
<td>Correctness (satisfaction of expectations)</td>
<td>Not achieved</td>
<td>Satisfactorily achieved</td>
<td>Highly achieved</td>
</tr>
<tr>
<td>Innovativeness</td>
<td>Nothing beyond the current state of the art</td>
<td>Satisfactorily innovative</td>
<td>Very innovative</td>
</tr>
</tbody>
</table>

- **Evaluation of the ODMS.** The ODMS was taken up and evaluated by three running VBEs, namely by IECOS, SMT and HELICE. These networks were evaluating on the improvement gained on the processes that they used to run previously, without using ODMS, namely evaluating the process of familiarising themselves with VBE concepts and the discovery of information from text. As shown in Figure 5.2, the validation of the ODMS returned mainly “satisfactory” or “excellent” for ODMS’s efficiency, and “good” for reliability, usability, correctness and innovativeness. Low decrease in consumption of resources and time is mainly caused by the fact that the VBE representatives needed to invest in new human resources to work with the ODMS (in parallel to their normal practice), and these also needed time to learn how to work with the ODMS.

![Figure 5.2 - Empirical validation of the ODMS](image)

*This Figure illustrates the results of the empirical validation of the ODMS system by representatives of three running VBE networks. It shows that the efficiency of the ODMS is validated as “mostly satisfactory” (i.e. value around “1”), while the reliability, usability, correctness and innovativeness are validated as entirely “excellent” (i.e. value “2”).*
5.3.2. Self-validation through feature analysis against existing models and systems

This Section addresses validation of the four main research results addressed in this thesis, including the two results from the conceptual part and two results from the functional part of the ColOnto system:

- Conceptual results: VBE-ontology and 4C-model of competency
- Functional results: ODMS and PCMS

At this stage, every result is compared against a number of related starts-of-the-art models or systems (of similar nature) developed through other research, as already identified and addressed in this thesis in Chapter 2. The conceptual and functional results are evaluated through a set of characteristics. Clearly, these characteristics are different for every result, but the values we have assigned for measuring them represent the same set, as outlined in table 5.2. Although the set of values for conceptual results is different from the set of values for...
the functional results, the generalised set of values suitable for both of them is also presented. In the following Sub-sections, the values are presented with their colour codes.

Table 5.28 Legend used for assigned values used for validation of different characteristics of ColOnto

<table>
<thead>
<tr>
<th>Values for conceptual results</th>
<th>Characteristic is not addressed</th>
<th>Characteristic is weakly addressed</th>
<th>Characteristic is sufficiently addressed</th>
<th>Characteristic is strongly addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values for functional results</td>
<td>Characteristic is not addressed</td>
<td>Characteristic is identified</td>
<td>Characteristic is only specified</td>
<td>Characteristic is successfully implemented</td>
</tr>
<tr>
<td>Generalised values for both type of results</td>
<td>Not applicable</td>
<td>Weak</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>Colour code for values</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.3.2.1. VBE-ontology

To validate the VBE-ontology it was compared to four existing ontologies related to the domain of collaborative networks, which are discussed earlier in this thesis in Chapter 2, Section 2.2.2.1, and also addressed in annex B, Section B.2.

Table 5.38 Comparison of the VBE-ontology against related CN ontologies

<table>
<thead>
<tr>
<th>Characteristics / Ontologies</th>
<th>TOVE enterprise ontology</th>
<th>AIAI enterprise ontology</th>
<th>JSI’s CNO ontology</th>
<th>PI ontology</th>
<th>VBE-ontology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addressing a variety of VBE concepts and relationships among them</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extensive annotation of concepts, including linguistic annotation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suitability for environments from different domain/business areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extensive and clear defining of concepts and relationships among concepts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correspondence to data and meta-data of environment’s management sub-systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formality needed for processing by software</td>
<td></td>
<td></td>
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<tr>
<td>Addressing domain/business area related concepts</td>
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<tr>
<td>Addressing technological/scientific terminology from literature and R&amp;D</td>
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<tr>
<td>Addressing norms and standards to be adapted for information management</td>
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<tr>
<td>Correspondence to environment reference models (e.g. ARCON)</td>
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<tr>
<td>Clarity</td>
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<tr>
<td>Coherence</td>
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<tr>
<td>Extendibility</td>
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<tr>
<td>Minimal encoding bias</td>
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<tr>
<td>Minimal ontological commitment</td>
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</table>
The characteristics for validation of this conceptual result (that appear as rows in the following table) are defined based on descriptions of: (1) CoLOnto objectives, i.e. reasons for the development the VBE-ontology (Section 1.2.3), (2) generic requirements for VBE-ontology (Section 2.4.1.1), and (3) specific stakeholders’ requirements for VBE-ontology (Section 2.4.2.1).

As shown below in table 5.3, the VBE-ontology is characterised as “very good” or “good” in relation to both the objectives and the requirements specified for it.

5.3.2.2. 4C-model of competency

To validate the 4C-model of competency it was compared to four existing competency models related to the domain of collaborative networks, which are already described earlier in this thesis in annex B (Section B.3). The characteristics for validation of this conceptual result (that appear as rows in the following table) are defined based on descriptions of: (1) objectives for the development of the competency model (Section 1.2.3) and (2) specific stakeholders’ requirements for the competency model (Section 2.4.2.3). As shown below in table 5.4, the response of the 4C-model to the objectives and requirements specified for it is evaluated as “very good”.

Table 5.4 - Comparison of the 4C-model of competency against related CN competency models

<table>
<thead>
<tr>
<th>Characteristics / Competency models</th>
<th>HR-XML competencies</th>
<th>Manufacturing competency</th>
<th>Competence cells</th>
<th>“s-a-r-C” model</th>
<th>4C-model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support for representing organisations in a uniform manner</td>
<td></td>
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<tr>
<td>Possibility to match against descriptions of (business) opportunities</td>
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<tr>
<td>Addressing the whole variety of identified competency characteristics</td>
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<tr>
<td>Addressing current availability of competency within an organisation</td>
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<tr>
<td>Addressing costs of competency provision</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Addressing validity of competency information</td>
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<tr>
<td>Being uniform and generic enough to suit all types of organisations</td>
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<td></td>
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<tr>
<td>Addressing the domain related characteristics</td>
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</table>

5.3.2.3. ODMS

To validate the ODMS it was compared to four related existing ontology management systems, which are described in this thesis in Annex B (Section B.4). The characteristics for validation of this conceptual result (that appear as rows in the following table) are defined based on descriptions of: (1) objectives for the development the ODMS (Section 1.2.3) and
As addressed below in table 5.5, the ODMS’s response to the objectives and requirements specified for it is evaluated mainly as “very good” or “good”. It also shows that the ODMS benefits from addressing the variety of state-of-the-art functionalities, while other existing ontology maintenance/management tools are typically developed to address a limited number of functionalities.

Table 5.5 - Comparison of the ODMS against other ontology management systems

<table>
<thead>
<tr>
<th>Characteristics / Ontology mng. sys.</th>
<th>OLS</th>
<th>Protege</th>
<th>TOKO</th>
<th>DOSG</th>
<th>ODMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support for ontology engineering, including semi-automated engineering</td>
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<tr>
<td>Support for compatibility with meta-data and data from related databases</td>
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<tr>
<td>Support for ontology based information discovery</td>
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<tr>
<td>Access rights and confidentiality for ontologies</td>
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<tr>
<td>Support for users who are not experts in ontologies</td>
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<tr>
<td>Independence from domain/business area</td>
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<tr>
<td>Organisation concepts through more than one type of relationship</td>
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<tr>
<td>Supporting ontology partitioning/decomposition and merging</td>
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<tr>
<td>Multi-user and collaboration support</td>
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<tr>
<td>Correctness</td>
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<td></td>
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<tr>
<td>Reliability</td>
<td></td>
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<tr>
<td>Usability</td>
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<tr>
<td>Efficiency</td>
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</table>

Clearly, the related ontology management systems classified here (e.g. Protege) have their own development targets, which is different than the ODMS, and thus do not measure well against our specific criteria. Also, please note that for the standard software quality characteristics (Correctness, Reliability, Usability, Efficiency), the OLS tool is not evaluated, since its implementation was not available at the time of completing this thesis.

5.3.2.4. PCMS

To validate the PCMS, its competency management functionalities only are evaluated, since the state-of-the-art literature lacks descriptions of organisations’ profile management. The PCMS’s competency management was compared to four existing competency management systems, which are described in this thesis in Annex B (Section B.5). The characteristics for PCMS (that appear as rows in the following table) are defined based on descriptions of (1) objectives for the development the PCMS (Section 1.2.3) and (2) specific stakeholders’ requirements for the competency management (Section 2.4.2.4).

As addressed below in table 5.6, the PCMS’s response to the objectives and requirements specified for it is evaluated mainly as “very good” or “good”. It also shows that the PCMS offers a wider variety of competency management functionalities, while other current approaches/systems address only a limited number of functionalities.

Please note that for the standard software quality characteristics (Correctness, Reliability, Usability, Efficiency), the state-of-the-art systems are not evaluated, since their implementations were not available at the time of completing this thesis.
Table 5.6 - Comparison of the PCMS’s competency management functionalities against other
competency management approaches

<table>
<thead>
<tr>
<th>Characteristics / Competency mng. sys.</th>
<th>Tremery</th>
<th>HR-XML</th>
<th>Mexican-Industry</th>
<th>AmbianCE</th>
<th>PCMS</th>
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</thead>
<tbody>
<tr>
<td>Matching competencies against descriptions of (business) opportunities</td>
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<tr>
<td>Viewing individual competencies of one organisation</td>
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<tr>
<td>Cataloguing aggregate competencies of the entire VBE</td>
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<tr>
<td>Structuring/cataloguing the competency data</td>
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<tr>
<td>Several views for the competency catalogue</td>
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<tr>
<td>Possibility to extend and/or change the domain of activity</td>
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<tr>
<td>Possibility to customise the competency model</td>
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<tr>
<td>Possibility of coping with large amounts of data</td>
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<tr>
<td>Specification of competency classes needed in the VBE</td>
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<tr>
<td>Development of new competencies</td>
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<tr>
<td>Evaluation and/or assessment of competencies</td>
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<tr>
<td>Competency gap analysis and elimination</td>
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<td></td>
</tr>
<tr>
<td>Correctness</td>
<td></td>
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<td></td>
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<tr>
<td>Reliability</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Usability</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Efficiency</td>
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</table>

5.3.3. Peer-reviewed validation – within scientific community

The components of the ColOnto system introduced in this thesis are also described in sixteen publications. As addressed earlier in Chapter 1, Section 1.6, four journal articles, six peer-reviewed conference papers, two book chapters and four technical project reports are published based on the results of this research. This showed that the research results produced in this thesis are validated by the scientific community.

The status of the author’s publications is shown in Figure 5.4. In this Figure all the publications are divided into four groups, one group per specific part of the ColOnto system. The groups are:

- **G1. ColOnto conceptual focus:** Design and development of VBE-ontology
- **G2. ColOnto conceptual focus:** Design and development of profile and competency model and sub-ontology
- **G3. ColOnto functional focus:** Maintenance and management of VBE-ontology (ODMS)
- **G4. ColOnto functional focus:** Management of profile and competency data (PCMS)

For each of the above groups its number of publications are listed. If more than two ColOnto components are presented in one paper, their related groups are attributed a fractional number of publications, e.g. 0.25 if all four components are addressed in one paper.
5.4. Lessons learned

This Section gives brief descriptions of the main lessons learned during the carrying out of the research presented in this thesis. These are divided into four main blocks: (1) Design of the VBE-ontology, (2) Development of sub-ontology for profiles and competencies, (3) Ontology-based support for VBEs, (4) Ontology-based support for boosting the VO creation.

5.4.1. Design of the VBE-ontology

Designing the VBE-ontology was the most important steps in the VBE-ontology development, since the approaches for both building and processing the ontology directly depends on this design. Below the lessons learned during the design step are addressed.

- **Partitioning of unified ontology.** In order to support information modelling and management for a large variety of functionalities and business processes of VBEs, the VBE-ontology needs to incorporate a large number of information types accumulated through and handled by these functionalities/processes. Addressing all this information in one ontology does not suitable serve purpose of ontology. It provides difficulties both for simultaneous use within different systems, and for its “digestion” by human users. Therefore the VBE-ontology needs to be partitioned at the logical and physical levels. In this thesis the logical partitioning into two main perspectives is suggested: (1) levels of concept-reusability, i.e. if a specific concept can be reused within all VBEs, or only within VBEs from the same domain, only within one specific VBE application, and (2) work areas, i.e. addressing specific VBE’s functionalities/business processes, such as: trust management, competency management, etc. This thesis introduces the notion of “sub-ontology” to represent an independent physical unit of the VBE-ontology.

- **Sub-ontology registry.** In order to maintain the VBE-ontology, a sub-ontology registry needs to be developed that supports integrability, mapping and versioning of the sub-ontologies of the VBE-ontology.

5.4.2. Development of sub-ontology for profiles and competencies

Collection of profile and competency data from VBE members is needed to provide a number of operations to boost the VO creation within VBEs. This Section outlines the lessons learned about the nature of profile and competency, as well as about the need for representation of the profile and competency models within the VBE-ontology.
• **Nature of profile.** There are not many state-of-the-art works on profile modelling. Organisations’ current profile models differ and mainly depend on the purpose for which they are developed and used. The VBE members’ profile model is developed in order to satisfy a number of activities for which the characteristic information about VBE members is needed.

• **Nature of competency.** There is no consensus on competency definitions in the state-of-the-art research. However, a number of common competency characteristics can be derived from the existing models and applied to the design of the VBE members’ competency model in order to make it consistent with the state of the art. These common elements represent the capability (that in other models can be also-called “process”, “activity”, “task” or “job”) and capacity (that is related to “resources”). To sum up, the main competency-related elements for VBE consists of capability, capacity, conspicuity and cost.

• **Organising profile and competency models within the VBE-ontology.** Representing profile and competency models in the VBE-ontology encountered a number of obstacles, e.g. it had to be adaptable to model any VBE domain or application environment. These models are represented at different concept-reusability levels of the VBE-ontology. In our approach, the generic part of the models is addressed at the core level, while the domain-related part is addressed at the domain level.

### 5.4.3. Ontology maintenance and management in VBEs

VBEs can benefit from a number of features that ontologies provide for information modelling and management. However, most of these aspects, such as ontology-based semi-automated database development or semi-automated information discovery, etc., are still being researched and are relatively immature. Therefore, VBEs need to develop this area in collaboration with ontology engineering specialist. The following ontology-based functionalities are needed for VBEs.

- Ontology visualisation, representation and navigation, to facilitate viewing the VBE-ontology and familiarisation with its concepts.
- An ontology library system to organise the sub-ontologies of the VBE-ontology.
- Ontology merging, integration and partitioning techniques to maintain the sub-ontologies of the VBE-ontologies.
- Ontology-based development of databases, namely converting ontology schemas to database schemas
- Ontology-based text-mining and information discovery

### 5.4.4. Profile and competency management in VBEs

Many of the requirements for competency management functionalities are addressed in the state-of-the-art literature. Competency needs to be managed for a number of different objectives, such as increasing competencies in organizations and exchange of competencies among organisations, etc. The set of competency management functionalities directly depends on the competency management objective. The important functionalities for the profile and competency management in VBEs represent:

- **Advanced collection of up-to-date VBE profile and competency information.** Collection of profile and competency data in VBEs is not an easy task, since every member needs to provide a large set of data. Therefore, some intelligent mechanisms for competency collection shall be developed.
- **Aggregation of profile and competency data.** An important function for VBEs is making aggregate competencies that help to represent the VBE-self in the market/society as a single entity.
5.4. Future research

This PhD research had resource and time limitations and therefore not all challenges identified for the ColOnto system could be addressed. During the period this research was carried out, a number of new complementary areas of research and development were identified to be pursued as further research. A few of these areas are presented below in this section.

1. During the R&D presented in this thesis, only the VBE sub-ontologies from the core-level were constructed. In the domain and application levels, a few sample sub-ontologies have been built. Other sub-ontologies need to be created in collaboration with the domain experts mainly to cater for the demand by each specific VBE domain or application.

2. More research needs to be done to develop a set of methodologies supporting ColOnto. These methodologies can basically be divided into two groups: methodologies for creation and evolution of the sub-ontologies of the VBE-ontology; and methodologies for both VBE-ontology management and ontology-based VBE information management.

3. The sub-ontologies of the current VBE-ontology have been implemented empirically for the most part and are informal. More formal sub-ontologies would be beneficial for ColOnto, since this would open up possibilities for reasoning about the sub-ontologies.

4. The thesis presents a number of functionalities for ColOnto are addressed as parts of the ODMS and PCMS management systems. During the development process of ODMS/PCMS, the need both for other complementary functionality as well as the extension of the current functionality was identified. One sample functionality is learning VBE terminology. While the ODMS supports the VBE administrator with remote introduction of VBE terminology to VBE members, the process of learning new terminology is still slow. Many VBE members do not have enough effort and patience to go through the interface for the VBE-ontology and read the definitions of the terms necessary. Some methodologies, such as those used in e-Learning, should be applied for teaching VBE members.
Annex A

Running VBEs

Below this Section addresses a list with those 1st generation VBE networks that participated in our research. Some of these networks, namely CeBeNetwork, HELICE, IECOS, and SMT, were also active members in the ECOLEAD project (as addressed in Chapter 1, Section 1.5). This supported establishment of a good everyday collaboration with them during the main phases of our research.

- **Automotive Cluster of Slovenia - GIZ ACS (Slovenia).** ACS [82] is a business association based on economic interest of its members uniting Slovenian automotive suppliers. Its members' aim is to reinforce the competitiveness and create greater added value. GIZ ACS is the central communication point of the automotive cluster and it is supported by infrastructure. ACS provides support for its members to integrate into the global automotive industry and to improve the range of their products and services. Therefore it accelerates the efficiency of its members by providing adequate research and development and cooperating with expert development and scientific institutions both in Slovenia and abroad.

- **CeBeNetwork (Germany).** CeBeNetwork [45] with headquarters in Bremen, has also branches in Hamburg, Bristol and Persons. The company focuses its activity on the IT sector engineering sciences sector and software development sector. CeBeNetwork realizes that professional and experienced workforce is the most important treasure. The cooperation with customers to reach the maximal benefits is its main goal. Moreover, the enterprise is a developer of custom-made solutions and a designer of innovative processes. CeBeNetwork Engineering & IT is the core company of the CeBeNetwork Group.

- **HELICE (Spain).** The “Fundación Hélice” [83] has been constituted for the development of the Andalucia aerospace sector in order to carry out the following activities. It is owned and reports to the Regional Governments (Junta de Andalucia) Ministry of Innovation, Science and Business (Consejería de Innovación, Ciencia y Empresa). The principal interest of the Helice Foundation (fundación Hélice) development of the Aerospace industry in Andalucia, especially in the area of research and development (i+i+D+i).

- **IECOS (Mexico).** IECOS [84] is an engineering and manufacturing firm that focuses on developing high added value solutions for our clients and allies through three different business units: IECOS supply services, IECOS engineering services, and IECOS technology. IECOS was founded in 2001 as part of the enterprises development program at Monterrey Institute of Technology (ITESM) in Mexico. The mission of ITESM is development of highly added value solutions for the manufacturing and engineering processes of its allies and clients using competitive human resources as well as latest technologies.

- **Swiss Microtech – SMT (Switzerland).** The Swiss Microtech Enterprise Network members [85] are leading manufacturers of high precision components located in close proximity. The group allows them to work synergistically, leveraging their individual capabilities for the maximum benefit of the OEMs. The members of Swiss Microtech combine long-standing expertise in the most complex machining operations with optimal process integration giving OEM’s total confidence that their outsourced business is carried out in best practice.
- **Toolmaker Cluster of Slovenia – TCS (Slovenia).** TCS [86] is a cluster of organizations working in the domain of design and production of tools, dies and special machines for mainly automotive industry. The aims of TCS include: (1) Regional development strategy, (2) Regional development infrastructure, (3) Increasing productivity, and (4) Increasing competitiveness.

- **VIRFEBRAS (Brazil).** The VIRFEBRAS [87][88] is a cluster of enterprises that works in a collaborative way and with common goals. Although they work collaboratively, each member remains with its own individual identity and independence to make business out of the cluster. VIRFEBRAS’ main goal is to offer products and services in the moulds and dies area to the market, using the facilities provided by the cluster involvement.

- **Virtuelle Fabrik AG (Switzerland).** Virtuelle Fabrik AG [89][90] is a project management and sales provider for the Virtuelle Fabrik community with over 50 companies, which was founded in 2001. Situated in the north-eastern part of Switzerland, it serves three regional clusters, one in north-western Switzerland, one in eastern Switzerland and one in southern Germany. The network consists of highly qualified engineering, design and manufacturing companies, procedure technicians, management consultants and various service companies. VF operates with high quality industrial products mainly combining SMEs and also subsidiaries of bigger companies.
Annex B

State of the art models and systems

This annex addresses details about a number of state of the art models and systems that are considered for development of the conceptual and functional parts of the ColOnto system presented in this thesis.

B.1. Ontology engineering

This Section addresses the state of the art considered for development of the VBE-ontology.

B.1.1. Definition and purpose

Ontologies have emerged as an alternative to represent knowledge [91]. Since the concept of “knowledge”, as well as the two other correlated concepts of “data” and “information” often appear in this thesis, their definition, rooted in [8], is provided below:

- **Data** represents a set of symbols. These symbols typically have no significance beyond their existence and do not have meaning on their own. In computer science, database cells generally hold data.
- **Information** represents data that has been given certain meaning by means of a relational connection. However this "meaning" does not have to be necessarily useful to the users. In computer science, a relational database makes information out of the data that is stored within it.
- **Knowledge** represents appropriate collections of information, intended to be useful for users. For example, when someone "memorizes" information, then they have amassed knowledge. This knowledge has useful meaning to them, but it does not provide an integration such as would infer further knowledge.

An **ontology** is related to knowledge in such a way that it defines a set of representational primitives with which to model a domain of knowledge [92]. One of the first definitions of an ontology in the computer science domain is addressed by [93], who state that “an ontology defines the basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary”. One of the most cited definitions is the one proposed by Gruber [63]: “an ontology is a formal, explicit specification of a shared conceptualisation”.

The common structure of ontologies is generally represented by **classes** (i.e. classifying main concepts of objects), **attributes** (i.e. representing properties of objects), and **relations** (i.e. identifying ways that objects can be related to one another) [94].

A wide variety of tasks related to processing information/knowledge is supported through the specification of ontologies. As examples of such tasks we can mention: natural language processing, geographic information retrieval, etc. [91]. Later on in Section 2.2.3 a number of ontology-based mechanisms are addressed. But here we first address the main purposes for developing ontologies.

According to [94], these purposes include:

- Sharing common understanding of the structure of information among both people and software agents,
- Enabling reuse of domain knowledge,
- Making the domain assumptions explicit,
- Separating domain knowledge from operational knowledge, and
- Analysing domain knowledge.
B.1.2. Degree of ontology’s formality

Both the amount of information and the degree of formality that is used to express it contribute to the content formality of the ontologies. In relation to the ontology content, two main types of ontologies are distinguished, namely the lightweight ontologies and the heavyweight ontologies [23], as describe below.

- A lightweight ontology is a structured representation of knowledge, which ranges from a simple enumeration of terms to a graph or taxonomy where the concepts are arranged in a hierarchy with the simple (specialisation, is-a) relationship defined between them.
- A heavyweight ontology adds more meaning to this structure by providing axioms and broader descriptions of knowledge. While a lightweight ontology is usually informal and sufficient to define concepts and the basic relationships between them, a heavyweight ontology is usually formal and contains axioms and definitions stated in logic to be used for reasoning.

B.1.3. Ontology’s scope and content

As addressed in [95], there are several types of ontologies. Each ontology type corresponds to a specific degree of context-independency of ontologies that enables their sharing and reuse in different environments. Ontology types include:

- Knowledge representation ontologies - applied to formalise knowledge within knowledge representation paradigms, used in frame-based languages (i.e. classes, subclasses, attributes, values, relations and axioms).
- General/Common ontologies - including vocabulary related to things, events, time, space, causality, behaviour, function, etc.
- Top/upper level ontologies - containing the very general concepts (independent from any field/area specificities) that can define almost everything (e.g. physical object, abstract concept, event, etc.).
- Core ontologies - comprising the general knowledge about a field or area of expertise that may include disciplines such as law, computer science, etc. These core concepts contain the root of different domain-specific ontology that represent different application domains.
- Domain ontologies - specialised within a specific field/area, providing specific vocabulary about the application domain.

B.1.4. Building the ontology

According to [94], in practical terms, construction of an ontology includes the following steps: (1) defining classes in the ontology, (2) arranging the classes in a taxonomic (subclass–superclass) hierarchy, (3) defining slots (for properties and relationships) and describing the range of values allowed for these slots, and (4) filling in the values for slots of the instances.

This Section first gives an overview of approaches for design and further engineering of ontologies. Then it provides more details about different types of manual development of ontologies. Lastly, it addresses a list of most commonly used ontology languages.

Engineering approaches. Depending on the availability of knowledge/information resources (e.g. text documents, database schemas, taxonomies, etc.) to support the construction of ontologies, four different approaches are introduced in the literature for ontology engineering (as summarised below, mainly based on [96]).
5. Developing and testing a methodology for building up an ontology - *incremental building, only by domain experts*.

6. Designing and developing alignment tools and mediating, even automated - “*integration*” of other, existing ontologies, e.g. addressed by [97], [98], and [99].

7. Using existing structured resources (e.g. database schemas, some types of thesauri, taxonomies) to design and develop ontology - *reverse-engineering methods and algorithms* [100].

8. Using existing semi-structured documents (e.g. the Web (especially XML pages), glossaries, and dictionaries) and unstructured resources (e.g. text corpora in general) - developing and adapting shallow and other types of *NL parsers*, e.g. addressed by [101], [102], [25], and [103].

**Engineering by experts.** Ontologies in general deal with the order and structure of reality that makes them a branch of philosophy. Thus, designing a substantial ontology is not a trivial task, and designing it so that it has relevance and value to a broad audience is even more challenging. The literature addresses five main approaches for ontological design of the environment knowledge (as summarised below based on [53]), while the combination of these approaches is also possible:

- **Inspiration approach** refers only to one individual viewpoint about the domain of knowledge.
- **Induction approach** addresses a specific case within the domain of knowledge.
- **Deduction approach** refers to a set of general principles about the domain of knowledge.
- **Synthesis approach** involves the integration of a set of existing ontologies, each of which provides a partial characterisation of the knowledge domain.
- **Collaboration approach** refers to a multiple individuals' viewpoints about the domain, possibly coupled with an initial ontology as an anchor.

**Ontology language.** In order to be shared among users, ontology has to be encoded in a special ontological format [104]. The format preserves all the knowledge that is inside the ontology.

- The most basic ontology language is XML, but it has many disadvantages, such as the lack of semantic description and the lack of commitment concerning the modelling primitives.
- RDF (Resource Description Framework) is based on the XML syntax but adds more features to support the ontology representation. The encoding in RDF is usually guided by an RDFS (RDF schema) that defines the relations between the terms and the way they can be used together. The RDFS solves some problems of XML, however it is appropriate only for encoding lightweight ontologies.
- A step towards heavyweight ontologies encoding was taken with OWL (Web Ontology Language), which is based on the Description Logics formalism. A main advantage of using OWL is that since the Description Logics is an established research field for many years, the OWL-based ontologies can benefit from the reasoning algorithms that have been intensively developed and optimised.

**B.2. Related ontologies**

This Section addresses two types of ontologies developed within past research. The first type represents the enterprise ontologies. The second type of ontologies represents a few ontologies developed to address some aspects of VBEs.
B.2.1. Enterprise ontologies

An enterprise ontology represents a collection of terms and definitions related to business enterprises [72]. Many enterprise ontologies are addressed in literature, for example those developed within the following projects: TOVE [105], Enterprise Project [106], O-Plan [107], ARPA [108], CEO [109], and ORDIT [110]. Two of them, namely the TOVE ontology and the Enterprise Project ontology are addressed below in this section.

B.2.1.1. TOVE enterprise ontology

The “TOVE enterprise ontology” was developed in the scope of the TOVE (TOronto Virtual Enterprise) project [105] aimed to create a data model with the following requirements:

- Providing a shared terminology for the enterprise that each agent can jointly understand and use, defines the meaning of each term (i.e. semantics) in a precise and as unambiguous manner as possible
- Representing the semantics in a set of axioms that will enable TOVE to automatically deduce the answer to many "common sense" questions about the enterprise

The TOVE ontology is a formal representation of the enterprise domain. It is designed to specify the tasks that arise in integrated supply chain management and enterprise engineering. The ontology is divided into several top-level concepts to segment the enterprise into general categories, including Activity, States, Causality, Time, Resources, and Organizational structure. The TOVE ontology is enriched by a set of axioms that define and constrain the interpretation of these terms. The ontology is formalized using first order logic that allows answering questions.

<table>
<thead>
<tr>
<th>ACTIVITY etc.</th>
<th>ORGANISATION</th>
<th>STRATEGY</th>
<th>MARKETING</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td>Person</td>
<td>Purpose</td>
<td>Sale</td>
<td>Time Line</td>
</tr>
<tr>
<td>T-Start</td>
<td>Machine</td>
<td>Hold-Purpose</td>
<td>Potential Sale</td>
<td>Time Point</td>
</tr>
<tr>
<td>T-End</td>
<td>Corporation</td>
<td>Purpose-Holder</td>
<td>For Sale</td>
<td>Calendar Date</td>
</tr>
<tr>
<td>Pre-Condition</td>
<td>Partnership</td>
<td>Objective</td>
<td>Vendor</td>
<td>Relative Time Point</td>
</tr>
<tr>
<td>Effect</td>
<td>Partner</td>
<td>Vision</td>
<td>Actual Customer</td>
<td>Duration</td>
</tr>
<tr>
<td>Doer</td>
<td>Legal Entity</td>
<td>Mission</td>
<td>Potential Customer</td>
<td>Duration Bounds</td>
</tr>
<tr>
<td>Sub-Activity</td>
<td>Organisational Unit</td>
<td>Goal</td>
<td>Customer</td>
<td>Time Interval</td>
</tr>
<tr>
<td>Activity Decomposition</td>
<td>Manage</td>
<td>Achieve</td>
<td>Reseller</td>
<td>Before</td>
</tr>
<tr>
<td>Authority</td>
<td>Delegate</td>
<td>Help Achieve</td>
<td>Product</td>
<td>Same or Before</td>
</tr>
<tr>
<td>Activity Owner</td>
<td>Management Link</td>
<td>Strategy</td>
<td>Asking Price</td>
<td>After</td>
</tr>
<tr>
<td>Event</td>
<td>Organisational Structure</td>
<td>Strategic Planning</td>
<td>Sale Price</td>
<td>Same or After</td>
</tr>
<tr>
<td>Plan</td>
<td>(Non-)Legal Ownership</td>
<td>Strategic Action</td>
<td>Market</td>
<td>Distance</td>
</tr>
</tbody>
</table>

Figure D.1: Concepts of the AIAI enterprise ontology (Source: [72])

This Figure addresses the five work areas of the AIAI enterprise ontology, namely “Activity”, “Organization”, “Strategy”, “Marketing”, and “Time”. For each work area, the Figure illustrates its main constituent concepts.
B.2.1.2. AIAI enterprise ontology

The “AIAI enterprise ontology” addressed by [72] is developed within the AIAI (Artificial Intelligence Applications Institute of the University of Edinburgh) as a part of the Enterprise Project [106] in order to provide a framework for enterprise modelling. The goal of the Enterprise Project is to provide a computer-based tool-set which helps to capture aspects of a business and analyze these to identify and compare options for the meeting of the business requirements.

This enterprise ontology was mainly created from scratch, but it was inspired and influenced by many other projects such as TOVE, O-Plan, ARPA, and ORDIT. The main role of this ontology includes:

- Acting as a communication medium between people, between people and implemented software systems, and between implemented software systems
- Assisting: (a) acquisition, representation, and manipulation of enterprise knowledge, (b) structuring and organization libraries of knowledge, and (c) the explanation of the rationale, inputs and outputs of the Enterprise tool-set modules

The enterprise ontology is formed of six sections, called “Meta-Ontology”, “Activity”, “Organization”, “Strategy”, “Marketing”, and “Time”, that are introduced for the convenience of exposition of the ontology. While the concepts on the Meta-Ontology are generic and constitute such terms as “Entity”, “Relationship” and “Attribute”, the concepts in other sections are more specific, as partially addressed below in Figure D.1.

B.2.2. Early VBE ontologies

There are only a few works addressing ontology development for VBEs presented in literature. Furthermore none of them address the VBE knowledge comprehensively, rather some parts of VBE knowledge related to a specific task performed in the VBE environment. Below is an overview of main state of the art works oriented towards the VBE ontology.

B.2.2.1. JSI’s CNO ontology

An early attempt to address an ontology for VBEs is done in the Joseph Stephan Institute (JSI) and presented in [29]. This ontology was developed empirically and aims at provision of common understanding among VBE members. This ontology is called “CNO ontology” and addresses the VBE as a subclass of Collaborative Networked Organizations (CNOs). It represents a narrow sub-set of the VBE related top-level concepts, namely only 34 concepts, such as “VBE”, “VO”, “Organization”, and “VBE Member”, their definitions and the relationships among the concepts. However since 2005 no extensions, as well as no utilization approaches for this ontology have been issued.

B.2.2.1. PI and CO Ontology

The ontology for VBE’s Performance Indicators (PIs) and VBE’s Collaborative Opportunities (COs) called “PI and CO Ontology” is presented by [30]. The main concepts of this ontology include: “PI”, “CO”, “Organization”, “VBE”, “VO”, “Performance requirement”, “Measurement objective”, etc. This ontology is developed to support measurement of performance of VBE members needed in VBEs to decide if these members can become the partners for a new VO. One specific aim of the ontology is to support selection of a minimal but sufficient sub-set of performance indicators, needed to measure performance of a VBE member in relation to a certain CO. A software tool implemented on top of this ontology provides functionality for annotation of PIs, as well as for searching of PIs.
B.3. Profile models

This Section describes the profile models from two example collections of organizations’ profiles. The first collection is a governmental-level (Dutch) and represents the profile register of the Dutch Chamber of Commerce. The second collection is a European-level and represents the profile register of the EU proposal submissions.

B.3.1. Register of the Dutch Chamber of Commerce

The Dutch Chamber of Commerce [111] has a trade register consisting of a large number of companies’ profiles. Each company/organization is presented with an extensive set of data classified by several categories. The basic categories include:

- **“Name/address” information**, including: business name or names and statutory name, place of business address and correspondence address, individual Chamber of Commerce registration number

- **Information concerning the roles and functions within companies**, including: all managers (e.g. directors), including the extent of their authority, supervisory directors of BVs (Besloten Vennootschap - private limited liability company) or NVs (Naamloze Vennootschap - public limited company form), all other registered officers (those with power of attorney) together with the extent of their authority, single shareholder (if present), any trustee (in the case of insolvency)

- **“Other” information**, including: date of establishment, legal form (see its description below), description of company, number of persons employed, information about capital (for BVs or NVs), information about all places of business, information relating to insolvency or suspension of payments

An example extract from the company’s basic information is illustrated in Figure D.2 (in Dutch).

There is also a second set of categories called **“actual activities of a company”**, that is used for market or academic research, or for a specialized mail campaign aimed at a particular target group. The main categories in this set include:

- **Size of the company**, including the number of persons who are employed for an average of at least 15 hours a week, and the owner and/or family members are included if they are also involved in the business

- **Addresses and information**, including: the addresses companies and legal entities in the trade register, telephone number, fax number, e-mail address or correspondence address, private address of the owner, partner, manager, company director or person with power of attorney, and the sole shareholder in the case of a BV, information about branches, the name of any receiver/trustee in the case of insolvency, any other companies with the same address

- **Summary of Figures**, including: that provide a guide to general trends in economic development, Figures to be used for such purposes as investigating economic development, Figures to be used as factual information when negotiating with local authorities, and Figures to be used as an argument for more land to be made available for this kind of industry
Figure B.2: An example business extract from the Dutch Chamber of Commerce register including the contact information about a company.

This Figure addresses an example profile of an organization registered in the Dutch Chamber of Commerce. The left side of the Figure addresses the classes of organization’s characteristics, such as name (see “naam”), address (see “adres”), etc. The right side addresses the specific characteristics of an example organization.

The third set of information categories is called “finances of a business” and represents the information about the annual accounts of organizations, including: the balance sheet (reflecting the position of the company at a given time and includes debts, assets, outstanding accounts), the profit and loss account (indicating what has been earned throughout the accounting year and what costs have been incurred, and reveals whether the company has made a profit or loss), notes to the annual accounts (the amount of details contained in the notes depends on the size of the company; for a small company, the notes may simply be a brief indication of how the balance sheet was compiled, together with a statement as to the number of employees, but for a large company, the notes may form a complete book, including details of directors' remuneration, for instance). The annual accounts support calculation of “ratios” to gain a picture of a company's financial position, namely its liquidity (ability of the company to meet its obligations in the short term), solvency (relationship between 'own' capital and 'borrowed' capital), and profitability (relationship between revenue and the capital used to produce that revenue, can be described as the relationship between the capital which the entrepreneur has invested in the business and the profit generated by this).

Additionally, the Dutch Chamber of Commerce suggests the following categories of the legal forms of organizations, including
• Legal forms which do not involve a legal person, where the entire personal assets are liable for obligations, such as Sole trader, General partnership (VOF - Vennootschap Onder Firma), Limited partnership (CV - Commanditaire Vennootschap), and Partnership
• Legal forms which do involve a legal person, where a legal form with a legal person has independent rights and obligations, such as Limited liability private company (BV), Association, and Foundation
• Freelancer
• Public limited company form (NV), which is rarely taken by start-up companies

The people can also be registered in the organizations’ profile. They belong to the following main types:
• The owner of the company
• Partners of the VOF or managing partners of the CV
• The managers of the legal entity

In relation to VBEs, the register of the Dutch Chamber of Commerce represents an example for categorization of organizations’ information, which is further reused for development of an approach for categorization of VBE member organizations’ profile information. The only restriction of the Dutch Chamber of Commerce register is that the organizations registered in it are all commercial, while VBE members can also be non-commercial, non-profit organizations. However, below an example related to the non-commercial organizations’ profiles in provided.

B.3.2. EU register of organizations

An example of a collection of profiles for non-commercial organizations is the EU register of organizations that are involved in proposal submission [112]. The structure of information used for these organizations includes sixty six different categories. The following categories are considered as more relevant to VBEs:
• Organization Legal Name
• Short name
• Department
• Postal address
• Legal national registration number (e.g. the Chambers of Commerce register)
• Activity type
• Legal Status, including: Governmental (local, regional or national public or governmental organizations e.g. libraries, hospitals, schools), International Organization (i.e. an international organization established by national governments), Joint Research Centre (i.e. the Joint Research Centre of the European Commission), Public Commercial Organization (i.e. commercial organization established and owned by a public authority), Private Commercial Organization including Consultant (i.e. any commercial organizations owned by individuals either directly or by shares), European Economic Interest Group, Private Organization, and Non Profit (i.e. any privately owned non-profit organization)
• NACE business area [74]
• Annual turnover
• Annual Balance sheet Total, having the following values: less than or equal to EUR 5 million, more than EUR 5 million or less than or equal to EUR 27 million, and more than EUR 27 million
• Number of employees, having the following values: 0 employee, 1 – 9 employees, 10 – 49 employees, 50 – 249 employees, 250 – 499 employees, 500 – 1999 employees, and 2000+ employees
• Independence, namely the name(s) of the company(ies) which own(s) 25% or more of the organization in case on non independent organization
• Owners, namely the legal name(s) of the organization(s) controlling the organization by 25% or more
• Affiliation
• Affiliated Organizations, namely the participant number, and the short name(s) of the organization(s) to which your organization is affiliated, the character of the affiliation(s) (Direct or Indirect control), and the organization legal name, short name, department, postal address, legal national registration number (e.g. the Chambers of Commerce register), activity type, legal status, NACE business area [74], annual turnover, annual balance sheet total, number of employees, owners, affiliation, etc.
• Authorized person

The above categories are also considered for the design of the member organizations’ profiles in VBEs. One example screenshot from the EU register of organizations is addressed in Figure D.3.

B.4. Competency models

This Sub-section subsequently presents several existing organization’s competency definitions and models as addressed in three disciplines: (1) intra-organization managerial sciences and industrial engineering, (2) inter-organization managerial sciences, and (3) networks managerial sciences. These disciplines are in interaction, but since their positioning of competency is different, the resulted competency models also differ.

The main objective for this Sub-section is to provide a comprehensive overview of different developed competency models in order to: (i) find the generic/common elements in the competency mode that can be reused for the development of VBE member’s competency model, and (ii) position the VBE’s model of competency, among existing competency models. Furthermore, we also aim to point the commonalities of the VBE competency model and those existing competency models (as addressed in Table 2.9) in order to prove that the VBE competency model belong to the main stream in the competency modelling related research, and provides a strong complementary contribution to that.

B.4.1. Intra-organization managerial sciences

In intra-organization managerial sciences competency is typically defined aiming at integration of competency models within strategic analysis. In industrial engineering (including production management and computer science) it is defined aiming at integration of “competency concept” within information systems, as a basis for performance analysis and for the development of the decision support system [113] [35].

B.4.1.1. Core competence notion

The concept of “core competence” was introduced in 1990 by Prahalad and Hamel [54]. They defined core competencies as “the collective learning in the organization, especially how to co-ordinate diverse production skills and integrate multiple streams of technologies”. A core competence is concerned to meet the following three conditions: (1) it provides customer benefits, (2) it is hard for competitors to imitate, (3) it can be leveraged widely to many products and markets.

The management of core competencies includes the four main tasks [114]: (a) selecting core competencies, (b) building core competence, (c) deploying core competence, and (d) protecting core competence. The notion of the core competence has popularized
a school of economic thought called the Resource-based View of the Firm [115]. The authors suggested that companies need to understand fully their core competencies in order to successfully exploit their resources. The collection and management of core competencies within an organization has two following main objectives: strategic planning and providing means for achieving better synergies among its various business units in a multi-business corporation.

The core competencies are distinguished from the individual competencies. While the individual competencies stand alone and are generally considered in isolation, the core competencies are the aggregates of competencies, where synergy is created that has sustainable value and broad applicability [116].

29. Short Name
   The short name chosen by the participant for this proposal. This should normally not be more than 20 characters and the same should be used for the participant in the A4 form.

30. Legal Registration No
    If applicable, please provide the organisation’s legal national registration number or code found in, e.g. the Chambers of Commerce register or the business register.

31. Activity Type
    Indicate the principal activity of your organisation. Please use one of the following codes:
    REC: Research (i.e. organisations only or mainly established for research purposes);
    HES: Higher Education (i.e. organisations only or mainly established for higher education/training, e.g. universities, colleges);
    IND: Industry (i.e. industrial organisations private and public, both manufacturing and industrial services – such as industrial software, design, control, repair, maintenance);
    OTH: Others

32. Legal Status
    Please use one of the following codes:
    GOV: Governmental (local, regional or national public or governmental organisations e.g. libraries, hospitals, schools);
    INO: International Organisation (i.e. an international organisation established by national governments);
    JRC: Joint Research Centre (i.e. the Joint Research Centre of the European Commission);
    PUC: Public Commercial Organisation (i.e. commercial organisation established and owned by a public authority);
    PRC: Private Commercial Organisation including Consultant (i.e. any commercial organisations owned by individuals either directly or by shares);
    EEI: European Economic Interest Group;
    PNP: Private Organisation, Non Profit (i.e. any privately owned non profit organisation).

33. Legal Status: ‘If ’PRC’, Specify’
    If you are a Private Commercial Organisation (PRC), please indicate the type of organisation (e.g.: SA, LTD, GmbH, independent person…).

Figure D.3: Example screenshot from the EU register of organizations
This Figure addresses a partial screen-shot from the description of organization’s characteristics in the EU register of organizations that are involved in proposal submission.

B.4.1.2. Core competence hierarchy

Many researchers have tried to highlight and further illuminate the meaning of core competence. Javidan [55] defines the competency hierarchy (see Figure D.4). In this definition, resources are the inputs into the organization’s value chain. Javidan categorizes resources into three groups of physical resources (e.g. equipment, location and assets), human
resources (e.g. manpower, management team, training and experience) and organizational resources (e.g. culture and reputation). Capabilities refer to the organization’s ability to exploit its resources. They consist of a series of business processes that manage the interaction among its resources. Capabilities (e.g. marketing capabilities, production capabilities, distribution capabilities and logistics capabilities) are functionally based. Competencies thus represent a cross-functional integration and coordination of capabilities. In a multi-business corporation, competencies are a set of skills and know-how housed in a SBU (Strategic Business Unit). Core competencies are skills and areas of knowledge that are shared across business units and result from integration and harmonization of SBUs’ competencies.

![Competencies Hierarchy and strategic hierarchy by Javidan (Source: [55])](image)

*This Figure addresses the formation and use of the competency concept for management of corporations. Namely it shows the way in which the competency definition is formed based on the resource definition (on the left side). It also shows the use of competency definition for different levels of corporation strategy planning (on the right side).*

**B.4.2. Inter-organization managerial sciences**

The inter-organization managerial sciences address the competencies of organizations that are needed when an organization is involved in some relationships with other organizations. However, there is still no organized network/alliance of these interacting organizations.

**B.4.2.1. HR-XML competencies schema**

This XML-based competencies schema was introduced within the HR-XML consortium [56] in 2001. The evolution of this schema is a part of an on-going project. The objective of this project is “the creation of an XML schema to provide trading partners standardized and practical means to exchange information about competencies within a variety of business contexts”. The HR-XML competencies schema allows the capture of information about evidence used to substantiate a competency and ratings and weights that can be used to rank, compare, and otherwise evaluate of the sufficiency or desirability of a competency. This schema is intended as a fragment or module that would be incorporated within broader process-specific schema. The competencies schema is particularly relevant to processes involving the rating, measuring, comparing, or matching an asserted competency against one that is demanded (for example, a skill required in a job description or requisition). In this paper we address the version of the schema dated April 2007 [117].

The competency, represented by the HR-XML schema, is defined as “a specific, identifiable, definable, and measurable knowledge, skill, ability and/or other deployment-related characteristic (e.g. attitude, behavior, physical ability) which a human resource may possess and which is necessary for, or material to, the performance of an activity within a specific business context”.

147
The main elements of competency in this schema include:

- **Taxonomy Id** is a code that identifies a specific competency taxonomy. However, the development of such taxonomies is stated to be outside the research on the HR-XML competencies schema.

- **Competency Id** is an identification code assigned to identify or classify a specific competency within the taxonomy.

- **Competency Evidence** is used to capture information to substantiate the existence, sufficiency, or level of a competency. The competency evidence might include test results, reports, performance appraisals, evaluations, certificates, licenses, or a record of direct observation, such as a report given by a former supervisor or other employment reference.

- **Competency Weight** allows the capture of information on the relative importance of the competency or the sufficiency required or other type of dimension. An extensible “type” attribute is available so that custom weights or dimensions may be specified. Multiple competency weights are permitted since more than one type might apply to the competency.

- **Competency** is another competency resulted from the decomposition the “top-level” competency.

While the HR-XML competency schema provides a good practical example of a competency model, it still addresses the competency as an attribute of the human resource (HR) within an organization, but not the attribute of the organization itself.

**B.4.3. Network managerial sciences**

The networks managerial sciences address competencies of organizations that are defined for networks of organizations, and particularly for VBEs. The three models presented here have different purposes, and therefore they also differ.

**B.4.3.1. Core competencies in manufacturing clusters**

In 1999, Molina and Flores [33] adapted the Cope Competency notion to the context of industrial clusters of organizations. They defined competences as the match of fulfilling the tasks defined for a new VO against the constituent skills provided by the cluster. In this scenario there is no representation of Core Competences Information, but there is a representation of constituent skills which is describing the capability to make products, perform process or use technologies (humans, practices/methods, resources). Therefore, constituent skills can be described using the information entities addressed in Figure D.5, which describes the elements and its relations using some basic UML notation:

The competency components addressed in Figure D.5 are defined as follows:

- **Products**: Represents the core products of companies or the cluster, which are attractive from the perspective of the customer and the market, and which make a substantial contribution to the company’s or cluster’s success.

- **Processes (Business Processes)**: All the core processes of a company. Examples of core process are: product development, order generation and fulfilment, integrated logistics, etc.

- **Skills (Technology)**: In this research skill was named as technologies. Technologies are theoretical and practical knowledge, human skills and abilities, artefacts that can be used to develop products and services.
- **Task**: It refers to the set of activities/operations that must be carried out in order to meet the business requirements given by the customer: manufacture of a product or offering a service.

![Diagram](image)

Figure D.5: Representation of Core Competences based on information entities by Molina and Flores (Source: [33])

*This Figure addresses definition of organization’s competency through its related entities, namely: task, product, process, and the combination of skills and technology.*

### B.4.3.2. Competence cells

A concept of the “competence cell” was introduced at the Collaborative Research Centre 457 in 1999 [118] and further extended in the works of Egon Müller and Sebastian Horbach, [57] [58]. A competence cell is defined as “the smallest autonomous performance unit able to create value, be indivisible and able to exist independently”. Thus, the competence cell is simply a small company or organization operating in the market or society. The network of such organizations is called a “competence cell-based network”. According to Müller, each competence cell is represented by the following characteristics:

- **Competence of humans**, arranged according to professional, methodological, social and personnel competencies
- **Available resources** (production areas, stocks, personnel, work equipment and auxiliary equipment, organizational and financial means)
- **Fulfilled task** or **executed function**

The networking of competence cells is considered as consisting of three following levels:

1. Regional network (i.e. a set of independent organizations in the market/society)
2. Institutionalized competence network (i.e. a VBE in terms of our research)
3. Production network (i.e. a VO in terms of our research)

The main objective for the introduction of the competence cells is to develop approaches for planning of production system in the competence cell-based networks.

### B.4.3.3. “s-a-r-C” competency qualification in networks of firms

Work of Xavier Boucher and Ali Harb [34] [35] tackles the issue of competence increase for individual firms within a network of firms, taking advantage of collaborative relationships. Specifically they address a multi-criteria decisional method, and a formalized decision process to qualify a specific competency.

The presented “s-a-r-C” model of competency is associated with three following characteristics: Situation, Actor, and Resource (see Figure D.6). Furthermore, the competency itself is defined as the result of
“the interaction between three components: the professional situations, the actors, and the resources”. Brief definitions of the three components of competency in this model follow:

- **Professional Situation** refers to a professional context linked with various tasks to be processed and various problems to be solved.
- **Actor** refers to the individual or collective human resources of the firm.
- **Resource** refers to the material resources characterized by the service they provide (i.e. material capabilities).

![Figure D.6: The “s-a-r-C” model of competency by Boucher et al.](Source: [34])

*This Figure addresses definition of organization’s competency as an instrument to respond to Professional Situations by involvement of Actors (i.e. human resources) and Resources (i.e. material resources).*

**B.5. Ontology maintenance and management**

This Section describes a specific set of functionalities as well as some management systems for maintenance and management of ontologies, as addresses in the state of the art literature.

**B.5.1. Ontology library**

In [32] [31] the concept of an Ontology Library System (OLS) is addressed. The OLS is defined as “an important tool in grouping and re-organizing ontologies for further re-use, integration, maintenance, mapping, and versioning”. Namely, the OLS offers the three following groups of functionalities:

- **Management**, including the services of: Storage (how to store the ontology), Identification (how to uniquely identify an ontology), and Versioning (how to maintain the changes of ontologies in an ontology library system)
- **Adaptation**, including the services of: Searching (how to search ontology from the ontology library system), Editing (how to add, delete and edit specific ontologies in the ontology library system), and Reasoning (how to derive consequences from an ontology)
- **Standardization**, including the services of Language support (which kind of standard ontology language is used in the ontology library system), and Upper-level ontologies support (is the ontology library system ‘grounded’ in any existing upper-level ontologies)

One of the main functionality in the OLS is integration/merging of its ontologies. Below a brief summary about the state of the art on ontology integration is addressed.
Ontology integration is defined in literature either as building of a new ontology reusing other available ontologies or as merging different ontologies on the same subject into a single ontology that “unifies” all of them [119]. Ontology integration is challenging. The main reason for this is that each ontology has its own naming conventions, philosophical orientation and design biases. One of the most used ontology languages such as OWL [22] currently is not expressive enough to support mapping among ontologies.

The ontology integration issue is addressed by many theoretical and practical works [119][97] [98] [99] [120]. For example, the approach defined in [98] addresses a set of steps for ontology integration, such as: identification of integration possibilities, identification of resulting ontology top-level blocks and modules, identification of assumptions and ontological commitments, identification of the knowledge for representation in each module, study and analysis of candidate/source ontologies, applying the integration operations, and analyzing the resulting ontology.

B.5.2. Ontology engineering environments

There are many existing free and commercial tools for engineering of ontologies. In [120] a survey of ninety four ontology engineering environments is addressed. These tools are characterised through their thirteen different features. Some of the features are basic, such as release date, version, language, input/output formats, etc. Other, more advanced, features of ontology environments are addressed below:

- **Web-support**: Support for Web-compliant ontologies (e.g. Uniform Resource Identifier - URI) and use over the Web (e.g. in browser clients).
- **Graph view**: The extent to which the built ontology can be created, debugged, edited and/or compared directly in graphic form.
- **Consistency checks**: The degree to which the syntactic, referential and/or logical correctness of the ontology can be verified automatically.
- **Multi-user support**: Features that allow and facilitate concurrent development of the built ontology.
- **Merging**: Support for easily comparing and merging independent built ontologies.
- **Lexical support**: Capabilities for lexical referencing of ontology elements (e.g. synonyms) and processing lexical content (e.g. searching/filtering ontology terms).
- **Information extraction**: Capabilities for ontology-directed capture of target information from content and possibly subsequent elaboration of the ontology.

None of the ontology environments defined in the survey addresses all of the above features at once. However, some of them address many of the required features, for example the Protégé editor [78][79].

Protégé is an ontology editor and a knowledge acquisition system that is constantly evolving. It is supported by a strong community of developers and academic, government and corporate users, who are using Protégé for knowledge solutions in areas as diverse as biomedicine, intelligence gathering, and corporate modelling. Protégé has a large number of specific functionalities, as well as a number of plug-ins providing a number of additional functionalities. It can be also either customised or extended. We have studied Protégé in order to check if some of its parts can be reused for the ODMS development.

Protégé organizes concepts in the generalisation hierarchy. Although, it has a special tab for representation of other types of relationship among concepts, it is not easy to follow the organization of concepts connected with the “part of” relationships. Protégé (through it plug-ins) has the following advanced features for ontology maintenance and management that are useful for ODMS:
- **Graph representation of concepts.** This feature facilitates navigation the concepts and understanding their interconnection. Although illustrating the concepts in the forms of graphs is beneficial, presenting of larger amount of information in the form of these graphs is limited.

- **Ontology mapping/merging.** This feature supports creation of a mapping between two ontologies, and executing the mapping using a mapping interpreter.

- **Linguistics support.** This feature supports introduction of synonyms for the concepts names.

### B.5.3. Information discovery and ontology discovery

Knowledge discovery [121] facilitates many information management systems by automatically obtaining knowledge. Knowledge can be discovered from a variety of sources, including sources that are structured (e.g. database and XML schemas), semi-structured (e.g. HTML-pages), or unstructured (e.g. plain text) documents [96]. Knowledge discovery approaches apply ontologies in order to set up and annotate the vocabulary and thesaurus needed for semantic discovery.

The knowledge discovered from text can be also further used to enrich the ontology. For example, the tool called tOKo addressed in [25] supports ontology-based knowledge discovery from text corpora such as HTML-pages and MS Word documents. It also supports selection of concepts in text-corpora and introducing them in the original ontology.

**tOKo** is an open source tool for text analysis and browsing a corpus of documents. It implements a wide variety of text analysis and browsing functions in an interactive user interface. An important application area of tOKo is ontology development. It supports both ontology construction from a corpus, as well as relating the ontology back to a corpus (for example by highlighting concepts from the ontology in a document).

Below is an incomplete list of features. If the feature is currently documented a link with more information is given.

- **Text corpus management:** tOKo creates an application from a collection of HTML or text documents, and from some weblog formats. A corpus may be hierarchical, while documents can be typed (e.g. folder vs. file distinction) and may contain a body of text as well as metadata.

- **Text analysis:** tOKo makes conclusions about: word frequency (by word class, by lemma, etc.), context (postfix, infix, prefix). It can also parse phrases (i.e. identification of word class information in English or Dutch. Moreover it supports a powerful pattern search facility.

- **Ontology development:** tOKo supports creation of concepts and specifies the relation to natural language of the concepts (including abbreviations and other alternate spellings). It also organises concepts in is-a and part-of hierarchies.

### B.5.4. Maintaining consistency between ontologies and databases

The approaches for transformation of abstract ontologies to valid database schemas are a part of the modern approaches for data structure generation. These transformation approaches solve the problem when the developers are proficient on database languages, but lack sufficient knowledge in the application domain. They also automate and speed up the database development.

For example the DOSG (Dynamic Ontology-based data Structure Generation) system presented in [122] addresses a number of transformation steps for automated translating an ontology to a database schema.
DOSG is a part of the TeleCARE system [24] that is developed in order to assist management of a specific type of Virtual Organizations. These VOs constitute of institutions and/or individuals (e.g. medical centres, insurance companies, family members) aimed at supporting everyday life of elderly people. DOSG aims to create a database for TeleCARE from a pre-defined ontology. The DOSG’s ontology transformation steps include:

- **Specification of mapping rules between the object oriented model and the relational schema.** Since the ontologies are the object oriented structures, while databases in many cases are relational, a number of rules should be defined for automatic conversion of ontologies into relational format.

- **Transferring of the relational representation of the ontology into SQL commands.** The resulted SQL commands represent the commands for creation of database tables.

- **Deployment of the database.** At this step the database tables are created from the SQL commands.

Mapping between ontologies and database can also support their evolution process. Below a brief summary of the state of the art research on ontology evolution is addressed.

The **ontology evolution** process is defined as the “timely adaptation of an ontology to the arisen changes in the consistent propagation of these changes in the dependent artefacts” [123]. It specially aims at: (1) enabling handling the required ontology changes, (2) ensuring the consistency of the underlying ontology and all dependent artefacts, (3) supporting the user to manage changes more easily, and (4) offering advice to the user for continual ontology reengineering.

The ontology evolution mechanism typically consists of the following six main phases [123]:

- **Change capturing** (such as business strategy evolution, the modification in the application domain, new user’s needs, additional functionality, etc.), that includes Structure-driven Change Discovery, Data-driven Change Discovery, and Usage-driven Change Discovery.

- **Change representation**, that is decomposition of complex changes into simpler ones and recording them in a suitable forms.

- **Change semantics specification**, that represents resolution of induced changes in a systematic manner, ensuring consistency of the whole ontology.

- **Change propagation**, that refers to bringing automatically all dependent artefacts into a consistent state after an ontology update has been performed.

- **Change implementation**, that includes (i) informing an ontology engineer about all consequences of a change request, (ii) applying all the (required and derived) changes, and (iii) keeping track about performed changes.

- **Change validation**, that helps ontology engineers to find out whether they have built the right ontology.

**B.6. Competency management**

This Section further addresses the state of the art on organization’s competency management as addressed in the three following disciplines: (1) intra-organization managerial sciences and industrial engineering, (2) inter-organization managerial sciences, and (3) networks managerial sciences. The main objective for this Section is to specify a set of both: competency management functionalities as well as competency-based management functionalities that are addressed in these three disciplines and can be reused for the PCMS development.
B.6.1. Intra-organization managerial sciences

In intra-organization managerial sciences and industrial engineering the organization competency management is considered as the means to both distinguish the organization from its competitors and provide it with a dominant position in the market. In [124] a competency management system is introduced, that is developed and applied at the Tremery plant, a subsidiary of French PSA group (Peugeot Citroen).

The Tremery system has the following main functionalities:

- Identification of acquired and required human competency
- Adaptation of competency schema to the domain
- Definition of strategic competency
- Structuring of the competency catalogue

B.6.2. Inter-organization managerial sciences

In inter-organization’s managerial sciences, that aim at providing the trading companies with the common models and mechanisms supporting their interaction, the organizations’ competency data needs to be shared among organizations. In these sciences, the main business processes related to competency management are still mainly performed inside every organization.

In [117] a number of functionalities for management of competency on top of the HR-XML competency model (see Section D.3.1.1) is addressed. These functionalities include:

- Assessments of competencies collected within an organization
- Evaluation of competencies by peers
- Different types of performance measurement that measure competencies
- Competency-based individual performance development planning and goal setting
- Competency-based performance monitoring & reporting
- Training curricula and individual courses that build competencies within an organization
- Competency-based career development systems
- Inventories of workforce competence (taxonomies for general and specialized uses)
- Selection procedures that assess competencies
- Succession planning systems
- Pay-for-competencies compensation systems
- Automated job descriptions
- Identification of the core competencies for strategic planning
- Human resources recruiting

B.6.3. Network managerial sciences

In network managerial sciences several works address needs, requirements and functionality identification for competency management in organization networks as follows:

A number of specified competency management functionalities are developed within the Mexican-Industry project [36]. This project was aimed at creation of a VBE network in metal-mechanic and plastic industrial sector in Monterrey, Mexico. The following functionalities are suggested for competency management:

- Deployment – identification of VBE members’ core competencies and matching them against the arisen business opportunities.
- Selection - selection of new VBE members with needed core competencies.
• Development – development of new core competencies in the VBE
• Protection – monitoring and evaluation of current set of core competencies.

In [37] a framework for creation of a VBE network in the mould and die sector in Brazil is addressed, which is called AmbianCE (in Portuguese: Ambiente de Criação de Empresas Virtuais). In this framework a number functions for competency management are introduced as follows:
  • Core-competency development and consolidation within organizations
  • Collection of member organizations’ core-competencies
  • Development a Competency Management program for a new VBE

B.7. ARCON reference model

This Section describes ARCON (A Reference Model for COllaborative Networks) that is applied for modelling of VBEs. This represents the way of VBE conceptualisation, that is useful for building of the VBE-ontology.

B.7.1. ARCON model of VBEs

Based on the ARCON modelling framework (see Section 1.2.2), a number of reference models for collaborative networks (CNs) are defined. The reference model for VBEs is prepared by the group of experts empirically through analysing the variety of VBE elements and characteristics related to different dimensions of the ARCON modelling framework [125]. This Section defines every of the two subspaces of the CN environment characteristics in more details and addresses the elements in the VBE reference model related to these subspaces. The VBE reference model is presented in literature in the form of tables. Below Table D.1 addresses the exogenous dimension, while Table D.2 addresses the endogenous dimension of the ARCON’s VBE reference model. These tables are prepared rooted in [125] and [17]. The VBE elements in these tables are summarised and they are life cycle independent. Please note that the abbreviation “LA” in these two tables stands for “long-term strategic alliance”.

The Exogenous Interactions subspace addresses the aspects related to the interactions between the CN, as a whole, and its surrounding environment. Therefore three natures of elements are considered for each dimension such as Network identity, Interaction parties, and Interactions. This subspace is also divided into four following dimensions:

  • Market dimension addresses the issues related to both the interactions with “customers”, representing potential beneficiaries, and “competitors” are covered by this dimension. Facets related to customers include elements such as the transactions and established commitments (contracts with customer), marketing and branding, etc. On the competitors’ side issues such as market positioning, market strategy, policies, etc. can be considered. Also part of this dimension are the purpose / mission of the CNO, its value proposition, joint identity, etc.
  • Support dimension addresses those issues related to support services provided by the third party institutions (outside of the CN) are to be considered under this dimension. The Certification services, auditing, insurance services, training, accounting, and external coaching are among example related issues.
  • Societal dimension addresses the issues related to interactions between the CN and the society in general are captured by this dimension. Although this perspective can have a very broad scope, the idea is to model the impacts that CN has or potentially can have on the society, for example its impact on employment, economic sustainability of a given region,
potential for attraction of new investments, as well as the constraints and facilitating elements (e.g. legal issues, public body decisions, education level) the society provides to the CN development.

- **Constituency** dimension addresses the issues related to the interaction with the universe of potential new members of the CN, i.e. the interactions with those organizations that are not part of the CN but that the CN might be interested in attracting them, are focused in this dimension. Therefore, general issues like sustainability of the network, attraction factors, what builds / provides a sense of community, or specific aspects such as rules of adhesion and specific “marketing” policies for members, are considered here.

Table D.1: Main exogenous interactions for VBEs

<table>
<thead>
<tr>
<th>Market</th>
<th>Support</th>
<th>Societal</th>
<th>Constituency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network identity</strong></td>
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<tr>
<td>- Mission statement</td>
<td>- (General) Strategy</td>
<td>- (Long term) Goals</td>
<td>- References / testimonials</td>
</tr>
<tr>
<td>- Network profile</td>
<td>- Who we are</td>
<td>- How to contact us</td>
<td>- Market strategy</td>
</tr>
<tr>
<td>- Marketing strategy</td>
<td>- Branding strategy</td>
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<tr>
<td><strong>Interaction parties</strong></td>
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<tr>
<td>- Customers</td>
<td>- Strategic customers</td>
<td>- Potential customers</td>
<td>- Competitors</td>
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<tr>
<td>- Direct competitors</td>
<td>- “Indirect” competitors</td>
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<tr>
<td>- (Potential) Suppliers</td>
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<tr>
<td><strong>Interactions</strong></td>
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<td></td>
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</tr>
<tr>
<td>- Advertising</td>
<td>- Broadcast</td>
<td>- Direct</td>
<td>- Bidding</td>
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<tr>
<td>- Bidding</td>
<td>- Handling inquiries</td>
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<th>Market</th>
<th>Support</th>
<th>Societal</th>
<th>Constituency</th>
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<tr>
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<td>- Profit</td>
<td>- Not for profit</td>
<td>- Governmental</td>
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<td>- NGO</td>
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<tr>
<td><strong>Interaction parties</strong></td>
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<tr>
<td>- Certification entities</td>
<td>- National institutions</td>
<td>- International institutions</td>
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<tr>
<td>- Insurance entities</td>
<td>- Private institutions</td>
<td>- Public institutions</td>
<td></td>
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<tr>
<td>- Logistics entities</td>
<td>- “Standard” registries</td>
<td>- Clearing centers</td>
<td>- Master data providers</td>
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<td>- Financial entities</td>
<td>- Banks</td>
<td>- Investors</td>
<td>- Sponsors</td>
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<td>- Coaching entities</td>
<td>- Advisers</td>
<td>- Individual external experts</td>
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</tr>
<tr>
<td>- Training entities</td>
<td>- Advisers</td>
<td>- Professional association</td>
<td>- Individual external experts</td>
</tr>
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<td>- Research institutes</td>
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<tr>
<td><strong>Interactions</strong></td>
<td></td>
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<tr>
<td>- Service acquisition</td>
<td>- Financial relation</td>
<td>- Technological service</td>
<td>- Training action</td>
</tr>
<tr>
<td>- Coaching action</td>
<td>- Guarantee action</td>
<td>- Knowledge transfer</td>
<td>- Consulting service</td>
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<tr>
<td>- Agreement establishment</td>
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<th>Market</th>
<th>Support</th>
<th>Societal</th>
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<tbody>
<tr>
<td><strong>Network identity</strong></td>
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<tr>
<td>- Legal status</td>
<td>- Legal entity</td>
<td>- Informal entity</td>
<td>- Values &amp; principles</td>
</tr>
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<td><strong>Interaction parties</strong></td>
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<td></td>
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<td>- Governmental organizations</td>
<td>- Social security</td>
<td>- City hall</td>
<td>- Civil defense</td>
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<td>- Interest groups</td>
<td>- Supporters</td>
<td>- Opponents</td>
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<td>- Regulatory bodies</td>
<td>- Other entities</td>
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<tr>
<td><strong>Interactions</strong></td>
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<td>- Political relations</td>
<td>- Seeking support</td>
<td>- Information transfer</td>
<td>- Broadcast</td>
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<td>- Direct</td>
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<td></td>
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Table D.2: Main Endogenous Elements for VBEs

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<th>Behavioral</th>
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<td><strong>Action</strong></td>
<td><strong>Concept</strong></td>
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<td>- Domain specific device</td>
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<td>- Prescriptive behavior</td>
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<td>- ICT resource</td>
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<td>- Cultural principles</td>
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<td>- Hardware</td>
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<td>- Regional traditions</td>
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<td>- Internet</td>
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<td></td>
<td>- Software</td>
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<td>- NGO culture</td>
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<td>- VBE Management System</td>
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<td>- Governance principles</td>
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<td>- VBE general principles</td>
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<td>- Contact person for Network</td>
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<td>- Incentive policies</td>
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<td>- Contact person for an Actor</td>
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<td>and rewarding</td>
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<td>- Info / knowledge / asset resource</td>
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<td>- Obligatory behavior</td>
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<td>- Profile/ competency data</td>
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<td>- VBE bylaws</td>
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<td>- Actor’s profiles data</td>
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<td><strong>Concept</strong></td>
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<td>- Physical constraints</td>
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<td><strong>Methodology &amp; Approach</strong></td>
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<td><strong>Concept</strong></td>
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<td>- Prescriptive behavior</td>
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<td>- Regional traditions</td>
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<td>- Business culture</td>
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<td></td>
<td>- ICT Use Guideline</td>
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<td></td>
<td></td>
<td></td>
<td>- Sanctions Principles</td>
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<td>- General law</td>
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<td></td>
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<td></td>
<td>- Contract &amp; agreement</td>
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<td>- VBE adhesion agreement</td>
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<td>- Agreement amendments</td>
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<td>- Constraint &amp; condition</td>
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<td></td>
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<td>- Confidentiality constraints</td>
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<td>- Legal constraints</td>
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<td>- Standards constraints</td>
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<td></td>
<td></td>
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<td>- Internal normative constraints</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Physical constraints</td>
</tr>
</tbody>
</table>
For the **Endogenous Elements subspace**, the elements that are defined in each of its dimension are classified into the following four categories according to their nature, such as: Active entity, Passive entity, Action, and Concept. This subspace is also divided into four following dimensions:

- **Structural** dimension addresses the structure/composition of the constituting elements of CNOs, namely its participants and their relationships, as well as the roles performed by those elements, and any other compositional characteristics of the network such as its typology, etc. are addressed by this dimension. This perspective is introduced and applied in many disciplines (e.g. systems engineering, software engineering, economy, politics, cognitive sciences, manufacturing, etc.), although with different “wording” and diversified tools.

- **Componential** dimension addresses the individual tangible/intangible elements in the CNO’s network, e.g. different resources such as the human elements, software and hardware resources, as well as information and knowledge are addressed by this dimension. Not all these elements are “physical” or tangible in a strict sense; in fact some are conceptual, e.g. the collected knowledge in CNs. Nevertheless, these elements together represent the “things” or components out of which the network is built. Furthermore, the componential dimension also consists of the intangible ontology and the description (meta-data) of the information/knowledge repositories that pertain to the CN.

- **Functional** dimension addresses the “base functions / operations” running/supported at the network, and time-sequenced flows of executable operations (e.g. processes) related to different phases of the CN’s life cycle are addressed by this dimension. The methodologies and procedures running at the CN are therefore also addressed by this dimension.

- **Behavioural** dimension addresses the principles, policies, and governance rules that either drive or constrain the behavior of the CN and its members over time, are addressed by this dimension. Included here are elements such as the principles of collaboration and rules of conduct, principles of trust, contracts, conflict resolution policies, etc.

### B.7.1. ARCON semantic indexing

The semantic indexing schema for ARCON [18] is suggested in order to formalize the ARCON’s reference models of CNs. Namely it provides unique identifiers for every element of ARCON’s reference models, that helps to uniquely position this element in the model. This strict positioning of the elements also reduces confusion in the structure of the ARCON models that may happen during the evolution of this system which can be done by several people/experts.

The ARCON’s index consists of a number of components. The elemental characteristics for the indexes of all elements in the ARCON reference model follows:

- **CN-type** (C)
- **Model-Intent** (M)
- **Sub-space-dimension** (SD)
- **Nature-of-element** (N)
- **Relative-order-number** (E)
- **Life-cycle-stages** (Ls)
- **Mnemonic-Label** (Lb)

A formalized description and examples of element-indexes are illustrated in Figure D.7. It introduces a “formula” on top, for each element-index. It further defines all elements in this formula one by one. It finally gives example indexes for 2 real ARCON elements at the bottom, namely the indexes for “ICT resource” and for “Market strategy”.

158
ARCON_element_index = (C, M, N, E, (Ls): Lb)

C ∈ {VBE, PVC, VO, VT, VLC, LA, GO, CNO}  * C is a type of Collaborative Network

M ∈ {GR, SM, IM}  * M is a Model Intent,

where:
GR is a General representation, SA is a Specific Modeling, and IM is a Implementation Modeling.

SD ∈ {E1, E2, E3, E4, I1, I2, I3, I4}  * SD is one Dimension in a Sub-space,

where in E (Endogenous Element) sub-space:
E1 is the Structural dimension,
E2 is the Componential dimension,
E3 is the Functional dimension,
E4 is the Behavioral dimension,

where in I (Exogenous Interaction) sub-space:
I1 is the Market dimension,
I2 is the Support dimension,
I3 is the Societal dimension,
I4 is the Constituency dimension.

N ∈ {AE, PE, AT, NI, IP, IL, IA}  * N represents the Nature of an ARCON’s element within a Sup-space,

where in E sub-space:
AE is Active entity,
PE is Passive entity,
AT is Action,
CP is Concept

where in I sub-space:
NI is Network Identity,
IP is Interaction Party,
IA is Interaction

* E is a list of e, numbers, separated by ‘,’ representing the hierarchic order in which ARCON’s element (or sub-element) appears within the (C.M.N) section, where: e ∈ N

* Ls is an ordered subset of {c, o, e, m, d} representing the CNO’s Life Cycle Stages for this ARCON’s element, and where:
  - c is Creation,
  - o is Operation,
  - e is Evolution,
  - m is Metamorphosis,
  - d is Dissolution

* Lb is a label / name for the ARCON’s element

Examples:
CNO,GR,E1,PE2:(coem): ICT resource
LA,GR,N1,N4,1:(coem): Market strategy

Figure D.7: Semantic-indexing for elements in the ARCON reference models
(Source: [18])

This Figure addresses the components of indexes for all specific elements in ARCON’s reference models.

In addition to the element-indexes, described above, for comprehensive representation, two other aspects of the ARCON elements are addressed and formulated, namely: (1) representation of the potential relationships that can be defined between different ARCON elements, and (2) representation of the specific model (also-called the model-representation-extension) being defined/developed for an element in the ARCON reference model of a CN.

Introducing semantic-indexes addressing these two other aspects of the ARCON elements is necessary for full representation of these elements with all their potential characteristics and features. The definitions of Relationships of each ARCON element with other elements (Rs), as well as the Model representation Extension of each element (X) are therefore addressed in Figure D.8.

The Model-representation-extension represents a specific model of the element, depending on its modelling intent, e.g. a semantic-index must be generated for the textual definition generated for an ARCON element at its “General representation” modelling intent level.

Figure D.8 first provides a “formula” on top, for each ARCON element. It further defines all elements in this formula one by one. It finally illustrates two example elements at the bottom, namely the extensions for the “ICT resource” and for the “Market strategy” ARCON elements.

Please note that while the formula on top represents the complete semantic index for each ARCON element, e.g. including the set of relationships, as well as the specific model (or a pointer to the specific model) within the defined index, the example at the bottom of the Figure, only exemplifies these two potential extensions of the ARCON element in a table.
format. Therefore, please do not confuse the representation of these examples with the format for representation of the semantic-index for the ARCON elements.

\[
\text{ARCON\_element} = (\text{ARCON\_element\_index, Rs, X})
\]

\(Rs^*\) is a set of tuples for relationships defined between this element and other ARCON elements, where for each \(r \in Rs\)

\[
r = (r\_name, \text{ARCON\_element\_index}), \text{and} \quad r\_name\text{ is the mnemonic name for a relationship with another ARCON's element}
\]

\(X^*\) is the model for the ARCON's element, where for each \(x \in X\)

\[
x = \text{textual\_definition} \text{ if } M=GR, \quad x = \text{specific\_model} \text{ if } M=SM, \quad x = \text{implementation\_model} \text{ if } M=IM
\]

Examples of ARCON's CNO reference model elements for the GR model intent:

<table>
<thead>
<tr>
<th>ARCON_element_index</th>
<th>R</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNO.GR.E1.PE.2(coemd): ICT resource</td>
<td>4. is related to Actor, CNO.GR.E1.AE.1(coemd): Actor</td>
<td>Entities characterizing the ICT equipment, software, and infrastructures used / shared in the network. It can include the architecture of the computer network supporting the collaboration.</td>
</tr>
<tr>
<td>CNO.GR.I1.NI.4.1(coem): Marketing strategy</td>
<td>6. is defined for Customer, CNO.GR.I1.IP.1(coemd): Customer</td>
<td>Marketing strategy – defining how the CNO concentrates its resources on the most relevant opportunities for achieving its goals and a sustainable competitive advantage.</td>
</tr>
</tbody>
</table>

Figure D.8: ARCON element representation
(Source: [18])

This Figure addresses the index-based representation of ARCON’s reference model. Namely, for every ARCON’s element it has a set of its relationship with other elements, as well as the definition or the model of its element.
Annex C

Questionnaires

This annex describes a number of questionnaires that are developed and used during specification of the research results presented in this thesis.

C.1. Profiles and competencies in existing VBEs (questionnaire Q-a)

A questionnaire called “Q-a” was prepared for studying the practice of the running VBEs related to the profile and competency modelling and management.

This questionnaire was distributed in September 2005 among more than ten running VBEs in Europe and Latin America. Not all of them have provided their answers for the questions. In relation to other VBEs, some of them faced difficulties with understanding the concepts of “profile” and “competency”; others, for example Swiss Microtech, did not handle their VBE members’ descriptions by that time.

In relation to the study of the current practices for VBE members’ profiles and competencies, the questionnaire Q-a aimed at investigation of the following main issues among others:

- What is the structure of the profiles?
- What for is the profile information collected?
- Are the profiles static (e.g. manually described in static HTML files) or dynamic (e.g. there is a database interface for profile data submission and displaying)?
- Who has rights and responsibilities for editing profiles?
- How often is the profile information updated?
- What are the main requirements for improving profile models and profile management?
- What is the structure of the competencies?
- Which functionalities/services for automated competency management exist?
• What are the main requirements for improving competency models and profile management?
  
  One screen-shot from the questionnaire Q-a is addressed below in Figure C.1.

C.2. Collection of stakeholders’ requirements (questionnaires Q-b1, Q-b2)

Two questionnaires, namely Q-b1 addressing VBE-ontology design and management, and Q-b2 addressing profile and competency modelling and management, were developed and distributed among the stakeholders in order to identify the requirements for the ColOnto solution.

The questionnaire Q-b1, distributed among the end-user stakeholders in summer 2007, had three main objectives. Since ontologies is a totally new instrument to support the management of networks of organizations, the first objective of the questionnaire “Q-b1” was to present the definition of an ontology to the end-users and explain its potential to support information management in VBEs. The second objective for Q-b1 was to identify if the end-users agree with the development of the VBE-ontology and the ODMS system to respond to the VBEs’ challenges. The third objective was to identify some specific requirements and preferences of the end-users in relation to the VBE-ontology and ODMS. Specifically, the questions of Q-b1 addressed the following questions among others:

• Do you wish to improve the common understanding of the terminology / concepts used within your VBE?
• Does your VBE have any classifications of the knowledge that is accumulated in your VBE (e.g. competency classifications, resource classifications, etc.)?
• Do you think that ontologies are too difficult to understand by the VBE actors / members in your VBE?

The questionnaire Q-b2 was prepared and distributed among the experts in the VBE field in September 2005 in order to complete the requirements for modelling and management of member organizations’ profiles and competencies [126]. The experts included both: (i) academic experts in the, namely the members of the SOCOLNET consortium [65]), and (ii) industrial experts in the VBE field, namely the companies that are members within the IECOS VBE. The answers of twelve academic experts and seven industrial experts were collected and analyzed. The specific issues addressed in the Q-b2 questionnaires include:

• What is the objective for handling VBE members’ profile?
• What is the structure of the VBE member profile?
• What is the difference between profile models for organizations from different domains of activities? What is the best way to obtain profile information?
• What is the best arrangement of the profile catalogue?
• What is the best navigation in the profile catalogue?
• What is the best search in the profile catalogue?
• How often should be profile catalogue updated?
• Is there a need and what are the main elements of the profiles for VBE-self and for VOs?
• What is the structure of the VBE member’s competency model?
• What information about VBE members is important during creation of a VO?
• How detailed should be the competency information?
• What are the needed functionalities for competency management?
C.3. Evaluation of ColOnto (questionnaires Q-c1, Q-c2)

Two questionnaires, namely Q-c1 and Q-c2 are developed to validate the ColOnto system by representatives of a number of VBE that have taken the ODMS and PCMS up. The main objective of these questionnaires was to identify the level of ODMS/PCMS effectiveness in relation to the main parameters characterising software quality, namely spent time, effort, and resources (for details about these parameters see Section 2.4.1.2). These questionnaires also characterised ColOnto in relation to its reliability, usability, correctness, and innovativeness. Specifically, the VBE representatives were asked if ODMS/PCMS improves a number of existing business processes in VBEs. Through these questionnaires, the end-users were also asked if the ODMS/PCMS have responded to their specific requirements. More details about these questionnaires follow:

Questionnaire Q-c1 was prepared for validation of the VBE-ontology and the ODMS and addressed validation of the following ODMS’s business processes among others:
(a) the activity of “introduction and sharing” of the VBE “general” concepts and terminology
(b) the activity of “introduction and sharing” of the VBE “domain” concepts and terminology
(c) the activity of “discovery and collection of data” for profiles and competencies

Questionnaire Q-c2 was prepared for validation of the profile and competency models and the PCMS in relation to the following PCMS’s business processes:
(i) the activities of “definition and modification” of profile and competency models
(ii) the activities of “customization to a specific VBE” environment and “evolution of the model for VBE” profiles and competencies
(iii) the activity of “collection/organizing” of more complete and comprehensive profile and competency information

One screen-shot from the questionnaire Q-c2 is addressed below in Figure C.2.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Resources</th>
<th>Time</th>
<th>Reliability</th>
<th>Usability</th>
<th>Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned Objective</td>
<td>Decreased or same</td>
<td>Decreased or same</td>
<td>Normal or better</td>
<td>Normal or better</td>
<td>Moderately achieved or better</td>
</tr>
</tbody>
</table>

Please fill the table below based on how you applied the tool in your VBE environment (or organization):

1. PCMS: Improving the identification/definition of types of profile/competency information needed from VBE member organizations.

<table>
<thead>
<tr>
<th>Value</th>
<th>Qualitative criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>Increase</td>
</tr>
<tr>
<td>Time</td>
<td>Increase</td>
</tr>
<tr>
<td>Innovation</td>
<td>Very innovative</td>
</tr>
<tr>
<td>Reliability</td>
<td>High</td>
</tr>
<tr>
<td>Usability</td>
<td>Normal/High</td>
</tr>
<tr>
<td>Expectation</td>
<td>Achieved</td>
</tr>
</tbody>
</table>

2. PCMS: Improving the customization (to specific VBE environment) and evolution of the model for VBE profiles and competencies.

<table>
<thead>
<tr>
<th>Value</th>
<th>Qualitative criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>Increase</td>
</tr>
<tr>
<td>Time</td>
<td>Decrease</td>
</tr>
</tbody>
</table>

Figure C.2: Screen-shot from the questionnaire Q-c2 filled in by CeBeNetwork

This Figure illustrates a screen-shot from the questionnaire Q-c2 filled in by representatives if a running VBE from Germany called CeBeNetwork. CeBeNetwork (as addressed in Annex A) actively participated in specification of requirements for the ODMS and PCMS, as well as in the trial and take up activities preformed for these software tool prototypes.
Annex D

Specification of core level of VBE-ontology

This Annex represents the specification of the ten core level sub-ontologies of the VBE-ontology [69] as introduced earlier in Section 2.5.2 of this thesis. These ten sub-ontologies are specified in the following sub-sections. Below Tables D.1 to D.7 present the main concepts within each sub-ontology of the core level of the VBE-ontology.

Please note that some concepts of the VBE-ontology, such as the “VBE participant” and the “VBE management system” are related to and thus must be addressed in several sub-ontologies at the same time, since they represent of the elements that bind those sub-ontologies. In the following tables, these concepts as well as their definitions are both distinguished through their italic representations. Furthermore, the textual definition of these “common” elements appears only once, in the table of the sub-ontology to which they are more closely related. Then all other related sub-ontologies refer to that table. For example, see “VBE Profile” and its definition in Table D.4, and see the “VBE Profile” in Table D.1 that refers to where the definition of VBE Profile can be found, by stating “See Table D.4”.

Please also note that besides the first element of each table, which represents the main element of its working area, all other elements are alphabetically sorted. Please also note, that this annex address only a main concepts due to the lack of space. All presented concepts are provided together with their definitions. The most important concepts in each sub-ontology are also provided together with meta-properties (i.e. synonyms and/or abbreviations). Furthermore, unlike the domain-level sub-ontologies addressed in the next Annex E, core level sub-ontologies do not have the deep subclass-superclass hierarchies of concepts. However, the existing sub-classes of the core sub-ontology concepts are mentioned in this Annex.

D.1. VBE-self sub-ontology

The VBE-self sub-ontology addresses the main concepts of VBE knowledge characterizing the VBE network as a whole. Particularly, it includes the “Virtual organizations Breeding Environment” concept and the concepts defining the main elements/components constituting VBEs, such as “VBE Actor”, “VBE Governance”, etc. The VBE-self ontology includes the largest numbers of concepts shared with other sub-ontologies, specifically it connects all other core level sub-ontologies together into the unified VBE-ontology. The main concepts of this sub-ontology are addressed below in Table D.1.

Table D.1: Concepts related to the VBE-self sub-ontology

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
</table>
| **Virtual organizations Breeding Environment (VBE)** | **ID:** VBE  
**Label:** Virtual organization Breeding Environment  
**Definition:** Virtual organization Breeding Environment (VBE) is an association of organizations and their related supporting institutions, adhering to a base long term cooperation agreement, and adoption of common operating principles and infrastructures, with the main goal of increasing both their chances and their preparedness towards collaboration in potential Virtual Organizations.  
**Kind:** Passive entity  
**Synonym:** Cluster, Network, Club  
**Abbreviation:** VBE, VO Breeding Environment  
**Subclass:** none  
**Attribute:** VBE_Profile |
<table>
<thead>
<tr>
<th><strong>Concept</strong></th>
<th><strong>Definition</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>VBE_Acquainenance</td>
<td>VBE_Acquaintance</td>
</tr>
</tbody>
</table>
| VBE_Life_Cycle | Part: VMS  
| VBE_Governance |  
| VBE_Value_System |  
| VBE_Bag_of_Assets |  
| VO |  
| VBE_actor | Sub-ontology: Core level VBE-self sub-ontology |
| **VBE Acquaintance** | **ID:** VBE_acquaintance  
| **Label:** VBE Acquaintance  
| **Definition:** VBE Acquaintance includes different external organizations (including other networks) which have relations with the VBE.  
| **Kind:** Concept  
| **Sub-ontology:** Core level VBE-self sub-ontology |
| **VBE Bag of Assets** | See Core level VBE Bag of Assets sub-ontology. |
| **VBE Gate Keeper** | **ID:** VBE_Gate_Keeper  
| **Label:** VBE Gate Keeper  
| **Definition:** The Gate Keeper acts as an interface to interactions that need to go beyond the VBE border. In this case, when a VBE does not have certain competency for example, and wants to get it from other sources outside the VBE, the VBE Gate Keeper will communicate with the Gate Keepers of other VBEs.  
| **Kind:** Concept  
| **Sub-ontology:** Core level VBE-self sub-ontology |
| **VBE Governance** | See Core level VBE Governance sub-ontology. |
| **VBE History** | See Core level VBE History sub-ontology. |
| **VBE Inheritance** | See Core level VBE History sub-ontology. |
| **VBE Life Cycle** | **ID:** VBE_Life_Cycle  
| **Label:** VBE Life Cycle  
| **Definition:** The life cycle of the VBE represents all the stages that a VBE may go through from the VBE creation stage to possible VBE dissolution stage.  
| **Kind:** Concept  
| **Part:** VBE_Life_Cycle_Stage  
| **Sub-ontology:** Core level VBE-self sub-ontology |
| **VBE Life Cycle Stage** | **ID:** VBE_Life_Cycle_Stage  
| **Label:** Life Cycle Stage  
| **Definition:** The VBE Life Cycle includes the following identified main stages: VBE creation (composed of the VBE initiation/recruiting and the VBE foundation), VBE operation, VBE evolution, VBE metamorphosis, and the VBE dissolution.  
| **Kind:** Concept  
| **Synonym:** Life Cycle Phase  
| **Subclass:** Creation  
| Operation  
| Evolution  
| Metamorphosis  
| Dissolution  
| **Sub-ontology:** VBE_Life_Cycle_Stage |
| **VBE Management System** | See Core level VBE Management System sub-ontology. |
| **VBE Participant / Actor** | See Core level VBE Actor sub-ontology. |
D.2. VBE Actor sub-ontology

The sub-ontology for VBE Actor, also referred to as VBE member and VBE actors in the literature represents the main types of data for characterizing each type of VBE actor/stakeholder. For example, it addresses the main properties of the “VBE actor” concept, such as “VBE Actor Profile” and “VBE Actor Role”. It also includes a classification of multiple roles which organizations play in VBEs, such as “VBE Member”, “VO Broker”, etc. This sub-ontology is represented in Table D.2 below.

Table D.2: Concepts related to the VBE participant/actor sub-ontology

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBE member profile</td>
<td>See Core level Profile and competency sub-ontology.</td>
</tr>
<tr>
<td>VBE Trust</td>
<td>See Core level Profile and competency sub-ontology.</td>
</tr>
<tr>
<td>VBE Value System</td>
<td>See Core level Profile and competency sub-ontology.</td>
</tr>
<tr>
<td>VBE-self profile</td>
<td>See Core level Profile and competency sub-ontology.</td>
</tr>
<tr>
<td>Virtual Organization</td>
<td>See Core level Profile and competency sub-ontology.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
</table>
| VBE Actor             | ID: VBE_Actor  
Label: VBE Actor  
*Definition*: VBE Actor / Participant is any organization within a VBE. Organizations in VBE represent: business entities providing products and services to the market that get involved in the VOs to gain quantitative profit, non-profit institutions that get involved in the VOs to gain qualitative profit, VO support institutions, for example: legal and contractual service providers, companies supporting individuals’ life maintenance (e.g. insurance and training companies), ministries, sector associations, chamber of commerce, environmental organizations, etc. Participants in a VBE can play different roles.  
*Kind*: Active entity  
*Synonym*: VBE Participant, VBE Stakeholder  
*Attribute*: VBE Actor Role, VBE Actor History  
*Sub-ontology*: Core level VBE Actor sub-ontology, Core level VBE-self sub-ontology |
| VBE Actor Role        | ID: VBE_Actor_Role  
Label: VBE.Actor.Role  
*Definition*: VBE Actor Role is a concept describing and characterizing the roles that can be performed by the VBE Actors. A role defines an expected behaviour for an actor in a given context.  
*Kind*: Concept  
*Synonym*: VBE Participant Role  
VBE Stakeholder Role  
*Subclass*: New VBE membership applicant  
VBE Member  
VBE Administrator  
VBE Advisor  
VBE Customer  
VBE Expert  
VBE External Stakeholder  
VBE Invited Organization  
VBE Ontology Provider  
VBE Support Institution  
VBE Support Service Provider  
VO-related Participation Role |
<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attribute:</strong></td>
<td>VBE Actor Responsibility</td>
</tr>
<tr>
<td><strong>VBE Actor Right</strong></td>
<td></td>
</tr>
<tr>
<td><strong>VBE Actor Liability</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Sub-ontology:</strong></td>
<td>Core level VBE Actor sub-ontology</td>
</tr>
<tr>
<td><strong>New VBE membership applicant</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ID:</strong> New_VBE_membership_applicant</td>
</tr>
<tr>
<td></td>
<td><strong>Label:</strong> New VBE membership applicant</td>
</tr>
<tr>
<td></td>
<td><strong>Definition:</strong> New member applicant is a Role played by an organization outside the VBE that has interest, applies to the VBE, and provides all needed information for becoming a member of the VBE.</td>
</tr>
<tr>
<td></td>
<td><strong>Kind:</strong> Active entity</td>
</tr>
<tr>
<td></td>
<td><strong>Sub-ontology:</strong> Core level VBE Actor sub-ontology</td>
</tr>
<tr>
<td><strong>VBE Actor History</strong></td>
<td>See Table D.5.</td>
</tr>
<tr>
<td><strong>VBE Actor Liability</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ID:</strong> VBE_Actor_Liability</td>
</tr>
<tr>
<td></td>
<td><strong>Label:</strong> VBE Actor Liability</td>
</tr>
<tr>
<td></td>
<td><strong>Definition:</strong> VBE Actor Liabilities are the obligations assigned to VBE Actors in relation to their Roles. For example, the VBE Member is obliged to respect and follow the VBE cooperation agreement.</td>
</tr>
<tr>
<td></td>
<td><strong>Kind:</strong> Concept</td>
</tr>
<tr>
<td></td>
<td><strong>Sub-ontology:</strong> Core level VBE Actor sub-ontology</td>
</tr>
<tr>
<td><strong>VBE Member Profile</strong></td>
<td>See Table D.4.</td>
</tr>
<tr>
<td><strong>VBE Actor Responsibility</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ID:</strong> VBE_Actor_Responsibility</td>
</tr>
<tr>
<td></td>
<td><strong>Label:</strong> VBE Actor Responsibility</td>
</tr>
<tr>
<td></td>
<td><strong>Definition:</strong> VBE Actor Responsibilities are the responsibilities assigned to a VBE Actor in relation to its Participation Role. For example, the responsibilities of VO Brokers include: to identify Needs and Trends in the Global Market, to classify them according the competitive advantage that prospective VOs would offer, to select ideas with more potential to configure successful VOs, etc.</td>
</tr>
<tr>
<td></td>
<td><strong>Kind:</strong> Concept</td>
</tr>
<tr>
<td></td>
<td><strong>Sub-ontology:</strong> Core level VBE Actor sub-ontology</td>
</tr>
<tr>
<td><strong>VBE Actor Right</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ID:</strong> VBE_Actor_Right</td>
</tr>
<tr>
<td></td>
<td><strong>Label:</strong> VBE Actor Right</td>
</tr>
<tr>
<td></td>
<td><strong>Definition:</strong> VBE Actor Rights are the rights assigned to a VBE Actor in relation to its Role. For example, the rights of VO Planners include: to access information about VBE capabilities, to know about VBE members qualities, to ask for negotiation mandate, etc.</td>
</tr>
<tr>
<td></td>
<td><strong>Kind:</strong> Concept</td>
</tr>
<tr>
<td></td>
<td><strong>Sub-ontology:</strong> Core level VBE Actor sub-ontology</td>
</tr>
<tr>
<td><strong>VBE Administrator</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ID:</strong> VBE_Administrator</td>
</tr>
<tr>
<td></td>
<td><strong>Label:</strong> VBE_Administrator</td>
</tr>
<tr>
<td></td>
<td><strong>Definition:</strong> VBE administrator is a Role of one VBE Actor, which is responsible for: the VBE operation and evolution, promotion of cooperation among the VBE members, identification and filling of the skill/competency gaps in the VBE by searching and recruiting/inviting new organizations into the VBE, the daily management of the VBE’s general processes, e.g. the assignment/re-assignment of access/retrieval rights to different actors in the VBE based in their responsibilities, the daily conflict resolution, the preparation of VBE’s bag of assets, and the making of common VBE policies, among others.</td>
</tr>
<tr>
<td></td>
<td><strong>Kind:</strong> Concept</td>
</tr>
<tr>
<td></td>
<td><strong>Synonym:</strong> VBE manager</td>
</tr>
<tr>
<td></td>
<td><strong>Sub-ontology:</strong> Core level VBE Actor sub-ontology</td>
</tr>
<tr>
<td><strong>VBE Advisor</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ID:</strong> VBE_Advisor</td>
</tr>
<tr>
<td></td>
<td><strong>Label:</strong> VBE_Advisor</td>
</tr>
<tr>
<td></td>
<td><strong>Definition:</strong> VBE advisor (or an advisory board) is a Role played by those VBE Actors that are responsible to elaborate strategic and/or enhancement recommendations to...</td>
</tr>
<tr>
<td>Concept</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| **the administrator.** | **Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology                                                                                                                                                       |
| **VBE Customer**   | **ID:** VBE_Customer  
**Label:** VBE Customer  
**Definition:** VBE Customer is a Role played by those VBE Actors that provide collaboration opportunities to the VBE and/or order VBE’s products/services.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology                                                                                                                                                       |
| **VBE Expert**     | **ID:** VBE_Expert  
**Label:** VBE Expert  
**Definition:** VBE Expert is a Participation Role played by those VBE Actors that support the VBE administration (and/or other VBE Members), advising them in solving some problems usually related to VBE management.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology                                                                                                                                                       |
| **VBE External Stakeholder** | **ID:** VBE_External_Stakeholder  
**Label:** VBE External Stakeholder  
**Definition:** External Stakeholder is a Participation Role played by those VBE Actors that represent organizations not registered in the VBE; however interested in participating in some of the VBE activities.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology                                                                                                                                                       |
| **VBE Invited Organization** | **ID:** VBE_Invited_Organization  
**Label:** VBE Invited Organization  
**Definition:** Invited Organization (Spot Member) is a Participation Role played by external VBE stakeholders, that are invited to the VBE in order to support some temporary requirements in the VBE, e.g. to fill in certain VBE competency gaps. They do not stay in the VBE during the full VBE life cycle.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology                                                                                                                                                       |
| **VBE Member**     | **ID:** VBE_Member  
**Label:** VBE Member  
**Definition:** VBE member is the basic Participation Role played by those organizations that are registered at the VBE, are ready to participate in the VBE activities and get involved in VOs.  
**Kind:** Concept  
**Synonym:** Regular VBE member  
**Attribute:** VBE Member Profile  
**Sub-ontology:** Core level VBE Actor sub-ontology                                                                                                                                                       |
| **VBE Ontology Provider** | **ID:** VBE_Ontology_Provider  
**Label:** VBE Ontology Provider  
**Definition:** Ontology Provider is a Participation Role of a VBE Actor that provides, adapts, evolves, and maintains the VBE common ontology.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology                                                                                                                                                       |
| **VBE Support Institution** | **ID:** VBE_Support_Institution  
**Label:** VBE Support Institution  
**Definition:** Support Institution is a Participation Role played by those VBE Participant organizations that for instance represent legal and contractual service providers, companies supporting life maintenance (e.g. insurance and training companies), ministries, sector associations, chamber of commerce, environmental organizations, etc.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology                                                                                                                                                       |
<p>| <strong>VBE Support</strong>    | <strong>ID:</strong> VBE_Support_Service_Provider                                                                                                                                                                       |</p>
<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
</table>
| Service Provider              | **Label:** VBE Support Service Provider  
**Definition:** Support Service Provider is a Participation Role played by those VBE Actors that provide the wide variety of services and support tools and mechanisms including both the base necessary services as well as the advanced assisting tools to support VBE Members' readiness to collaborate in VOs.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology |
| VO Broker                     | **ID:** VO_Broker  
**Label:** VO Broker  
**Definition:** Opportunity Broker is a Participation Role played by a VBE Actor that identifies and acquires new collaboration opportunities (business opportunities or others), by marketing VBE competencies and assets and negotiating with (potential) customers. There is also the possibility of this opportunity brokerage role being played by an outside entity, providing a service to the VBE.  
**Kind:** Concept  
**Synonym:** Opportunity broker  
**Sub-ontology:** Core level VBE Actor sub-ontology |
| VO Coordinator                | **ID:** VO_Coordinator  
**Label:** VO Coordinator  
**Definition:** VO coordinator is a Participation Role played by a VBE actor that coordinate a VO during its life cycle in order to fulfil the goals that were set by the collaboration opportunity that triggered the VO.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology |
| VO Partner                    | **ID:** VO_Partner  
**Label:** VO Partner  
**Definition:** VO partner is a base Participation Role of a VBE Actor played in a VO.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology |
| VO Planner                    | **ID:** VO_Planner  
**Label:** VO Planner  
**Definition:** VO Planner / Business Integrator is a Participation Role performed by a VBE actor that in face of a new collaboration opportunity (designed by an opportunity broker), identifies the necessary competencies and capacities, selects an appropriate set of partners (VBE members and even outsiders in case there is not enough competencies and/or capacities inside the VBE), and structures the new VO. In many cases the roles of opportunity Broker and VO planer are performed by the same actor.  
**Kind:** Concept  
**Sub-ontology:** Core level VBE Actor sub-ontology |
| VO-related Participation Role | **ID:** VO-related_Participation_Role  
**Label:** VO-related Participation Role  
**Definition:** VO-related Participation Role is an abstract concept used for classification of the VBE participant’s roles played in VOs.  
**Kind:** Concept  
**Synonym:**  
**Abbreviation:**  
**Subclass:** VO Broker  
VO Coordinator  
VO Partner  
VO Planner  
**Sub-ontology:** Core level VBE Actor sub-ontology |
### D.3. VO sub-ontology

The VO sub-ontology represents the main types of concepts that characterize a Virtual Organization. The VO sub-ontology includes the main classes of knowledge characterizing the Virtual Organization. For example, it addresses the main attributes of VOs, such as “VO Partner” and “VO Model”. The specific VO related concepts, term and definitions were extracted mainly from [127]. This sub-ontology is represented in Table D.3 below.

Table D.3: Concepts related to the VO sub-ontology

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Organization (VO)</td>
<td>Virtual Organization (VO) represents a temporary alliance of diverse organizations that form a collaboration network, sharing knowledge, skills, and resources towards provision of value-added products and services and that resort to a computer network and associated tools to support their cooperation. Virtual enterprises and extended enterprises are particular cases of the VO. &lt;br&gt;Abbreviation: VO, VE &lt;br&gt;Synonym: Virtual Enterprise</td>
</tr>
<tr>
<td>VO Agreement</td>
<td>VO Agreement / Contract is an agreement reached among VO Partners that outlines the legal framework for their co-operation and tasks distribution in a VO.</td>
</tr>
<tr>
<td>VO Inheritance</td>
<td>See Table D.5.</td>
</tr>
<tr>
<td>VO Model</td>
<td>VO Model is a schema (e.g. in XML) that is used for representing all the information supporting VO Creation within VBE environments. This schema is fulfilled during the steps involved in the VO Creation process.</td>
</tr>
<tr>
<td>VO Partner</td>
<td>See Table D.2.</td>
</tr>
<tr>
<td>VO-self Profile</td>
<td>See Table D.4.</td>
</tr>
</tbody>
</table>

### D.4. Profile and competency sub-ontology

The VBE profile and competency sub-ontology includes the main classes of knowledge for characterizing profiles and competencies of VBE member organizations. It mainly addresses the elements of profiles and competencies (e.g. “VBE General Data”, “VBE Competency” for profile, and “Capability”, “Conspicuity” for competencies), as well as their sub-classes (e.g. the “Resource” has several sub-classes, such as “Human Resource” and “Physical Resource”). This ontology is fundamental for VBEs, since it addresses the main classes of knowledge that the VBE members must define in order to introduce themselves in the VBE. Regular VBE members must understand the meaning of all profile and competency related concepts.

The models of profiles and competencies, presented in the VBE profile and competency sub-ontology, are further addressed in Chapter 4 of this thesis. Specifically that Chapter addresses the reasoning made behind the profile and competency models. Furthermore, Chapter 5 of this thesis addresses the supporting features provided by this sub-ontology to the Profile and Competency Management System (PCMS), particularly it exemplifies the usefulness of ontologies for VBEs. This sub-ontology is addressed in Table D.4 below.

Table D.4: Concepts related to the profile (and competency) sub-ontology

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBE Profile</td>
<td>VBE profile consists of the set of determining characteristics (e.g. name, address, capabilities, etc.) about each VBE entity (i.e. VBE Actor, VO, and VBE-self), collected in order to: (a) distinguish and compare each VBE entity with others, (b) analyze the suitability of each VBE entity for involvement in some specific line of activities / operations.</td>
</tr>
<tr>
<td>Concept</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Competency</td>
<td>Competencies in VBEs are a fundamental part of a Profile and represent up-to-date information about capabilities, capacities, costs, as well as conspicuities of each VBE member organization and illustrating the accuracy of their provided information, all aimed at qualifying organizations for VBE participation, and mostly oriented towards their VO involvement. (Ermilova and Afsarmanesh, 2008)</td>
</tr>
<tr>
<td>Capability</td>
<td>Capabilities are those characteristics of Competency that represent the abilities of organizations, e.g. their processes and activities. When collective business processes are modelled for a new VO, the VO planner has to search for specific processes or activities that can be performed by different organizations, in order to instantiate the VO model.</td>
</tr>
<tr>
<td>Capacity</td>
<td>Capacities are those characteristics of Competency that represent the existing free capacities of resources that are needed to perform any and all capabilities. Specific capacities of organizations are needed to fulfill the quantitative values of capabilities, e.g. amount of production units per day. If the organization’s capacity of one member (i.e. the organization’s free capacity) for a specific capability is not enough for a new VO, another VBE member (or a group of other VBE members) who can offer the same capability shall be invited to the VO.</td>
</tr>
<tr>
<td>Conspicuity</td>
<td>Conspicuities are those characteristics of Competency that represent means for validity of information provided by VBE members about their capabilities, capacities and costs. The conspicuities in VBEs mainly include either certified or witnessed documents, such as certifications, licenses, recommendation letters, etc. Synonym: Evidence</td>
</tr>
<tr>
<td>Cost</td>
<td>Costs are characteristics of Competency that represent the costs of products/services provision in relation to one capability. These are needed by the VO Planner to estimate if invitation of a specific group of members to a VO does not exceed the planned VO budget.</td>
</tr>
<tr>
<td>Financial Information</td>
<td>Financial Information is a part of a Profile addressing information about finances of an organization, such as total revenue, profit account, etc.</td>
</tr>
<tr>
<td>Human Resource</td>
<td>Human resource is a sub-class of Resource that refers to the characteristics of employees within the organization.</td>
</tr>
<tr>
<td>IT Resource</td>
<td>IT (technological) resource is a sub-class of Resource that refers to hardware and software within the organization.</td>
</tr>
<tr>
<td>Physical Resource</td>
<td>Physical resource is a sub-class of Resource that refers to buildings, machines, equipment, transport facilities, knowledge assets physically recorded and preserved within the organization.</td>
</tr>
<tr>
<td>Practice</td>
<td>Practice is a characteristic of an organization’s Capability that represents a technique, a methodology, or a procedure that is used in the organizations to perform a job. Practices are used in order to improve business processes in the organization.</td>
</tr>
<tr>
<td>Private Profile</td>
<td>Private Profile represents a complete and detailed set of profile information, intended only for internal use (e.g. only by VBE administration).</td>
</tr>
<tr>
<td>Process</td>
<td>Process (e.g. a business process) is a characteristic of a Capability representing a structured and measured, managed and controlled set of interrelated and interacting activities that uses resources to transform inputs into specified outputs. Synonym: Activity</td>
</tr>
<tr>
<td>Product</td>
<td>Product (Goods or Services) is a characteristic of the organization’s Capability representing an artefact that is created within some processes and that can be offered to a market.</td>
</tr>
<tr>
<td>Public Profile</td>
<td>Public Profile represents a limited subset of the private profile information intended to be shown outside the VBE.</td>
</tr>
<tr>
<td>Resource</td>
<td>Resource is a characteristic of organization’s Capability that represents a consumable element in a process that performs a number of operations which can transform some tangible / intangible inputs into some outputs.</td>
</tr>
<tr>
<td>Restricted Profile</td>
<td>Restricted Profile is a restricted subset of profile information, intended for a certain group of users within the VBE.</td>
</tr>
<tr>
<td>VBE Participant / Actor Profile</td>
<td>The Profile of VBE Participant / Actor is one kind of the VBE profile, consisting of the set of determining characteristics about a VBE Actor.</td>
</tr>
</tbody>
</table>
### D.5. History sub-ontology

The History sub-ontology represents the main concepts related to characterizing historical information stored in VBEs. For example, it addresses the types of VBE's history, such as “VO Inheritance”, “Cooperation History”, “Collaboration History”, etc. The history sub-ontology is addressed in Table D.5 below.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBE History</td>
<td><em>VBE History represents the past records of events and facts about VBE entities (i.e. VBE Actors, VOs, and the VBE-self).</em></td>
</tr>
<tr>
<td>Applied Practice Record</td>
<td>Applied Practice Record addresses a record detailing the past or present practices applied at the organization.</td>
</tr>
<tr>
<td>Collaboration Record</td>
<td>Collaboration Record addresses a record about past or present collaboration of an organization in any VOs.</td>
</tr>
<tr>
<td>Cooperation Record</td>
<td>Cooperation Record addresses a record about past or present cooperation of an organization in any VBEs.</td>
</tr>
<tr>
<td>Delivered Product Record</td>
<td>Delivered Product Record addresses a record about past or present products (i.e. services and goods) delivered by an organization.</td>
</tr>
<tr>
<td>Performance Record</td>
<td>Performance Record addresses a record about past or present performance of an organization.</td>
</tr>
<tr>
<td>VBE Inheritance</td>
<td>VBE Inheritance is a set of documents about a VBE that remains after it is dissolved.</td>
</tr>
<tr>
<td>VBE Participant/Actor History</td>
<td>Participant/Actor History is a collection of records about the past and present Performance of the VBE Participant, as well as the records of its cooperation in VBEs and collaboration in different VOs.</td>
</tr>
<tr>
<td>VO Inheritance</td>
<td>VO Inheritance constitutes some documents/information which VBE inherits after VOs dissolve.</td>
</tr>
</tbody>
</table>

### D.6. Bag of Assets sub-ontology

The Bag of Assets sub-ontology includes the knowledge concepts characterizing the main types of documents and software tools available within the VBE’s Bag of Assets. For
example, concepts in this ontology include “Lessons Learned”, “Commercial Software”, and “Document of Interest”. The Bag of Assets sub-ontology is addressed in Table D.6 below.

Table D.6: Concepts related to the bag of assets sub-ontology

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bag of Assets</td>
<td>Bag of Assets provides a number of elements that are interesting and useful for sharing among the VBE Members such as the general sharable information provided in some documents, software tools, lessons learned, etc.</td>
</tr>
<tr>
<td>Lessons Learned</td>
<td>Lessons Learned is an element of the Bag of Assets that is gradually collected through VBE members’ contributions. It enables the knowledge gained from past experiences to be applied to current and future projects. Its intent is to avoid the repetition of past failures and mishaps, as well as share observations and best practices. Through this resource, members seek to facilitate the early incorporation of quality into the design of their products and services.</td>
</tr>
<tr>
<td>Shared documents</td>
<td>Shared documents collected in the Bag of Assets include for example: general policies in the form of documents, books, leaflets, etc., to help (new and old) VBE members to easily follow the guidelines of a VBE. It may include information of common interest, specific to the sector, some sample contracts to speed up the VO contracting phase, and some general legal documents related to the VBE sector/domain.</td>
</tr>
<tr>
<td>Software tools</td>
<td>Software tools collected in the Bag of Assets include for example: the billing software, document-management software, etc., contributed by VBE Participants to be shared with others, aimed at facilitating some business processes required by VBE Participant organizations.</td>
</tr>
</tbody>
</table>

D.7. Trust sub-ontology

The Trust sub-ontology represents the main concepts of knowledge characterizing trust establishment in VBEs. For example, it addresses the definition of “VBE Trust” through “Trust Objective” and “Trust Perspective”. It also includes two classes of “Trust Actors” in VBEs such as “Trustee” and “Trustor”. The specific concepts for this sub-ontology were obtained from [128]. The Trust sub-ontology is addressed in Table D.7 below.

Table D.7: Concepts related to the trust sub-ontology

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBE Trust</td>
<td>VBE Trust is a state of connectedness among people or organizations or is a state involving mutual dealing among people or parties. The trust relationship refers to the state of connectedness between a trustor and a trustee whose intensity is characterized and based on the trustworthiness level [128]</td>
</tr>
<tr>
<td>Client Service Related Perspective</td>
<td>Client Service Related Perspective is a Trust Perspective referring to those clients who consider the mechanisms and tools that the VBE will use to serve them as primary aspect when assessing the trustworthiness of the VBE. These include: customer portal, customer registration function, etc.</td>
</tr>
<tr>
<td>Financial / Economical Perspective</td>
<td>Financial / Economical Perspective is a Trust Perspective referring to those trustees who consider financial factors as the primary aspect when assessing trustees’ trustworthiness.</td>
</tr>
<tr>
<td>Managerial / Behaviour Perspective</td>
<td>Managerial / Behaviour Perspective is a Trust Perspective referring to those trustees who consider the behaviour or the managerial aspects as the primary aspect when assessing its trustworthiness. In this manner, their trust assessment is based on how well the trustee professionally behaved and how well it uses its power when it gets into the management position. Thus, it focuses on how the trustee had been interacting and working with other organizations in the past.</td>
</tr>
<tr>
<td>Organizational Perspective</td>
<td>Organizational Perspective is a Trust Perspective referring to those trustees who consider organizational setting and strength as a primary aspect when assessing trustworthiness of the trustees. Their points of views for trustworthiness is based on the internal settings of an organization which play an important contribution to trustee’s trustworthiness such as size of an organizations, organization coverage,</td>
</tr>
<tr>
<td>Concept</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Profile related Perspective</strong></td>
<td>Profile related Perspective is a Trust Perspective referring to those clients who consider capabilities and general good picture of the VBE as primary aspect when assessing the trustworthiness of the VBE. These include: VBE public profile including list of members and list of VOs, VO public profile including partners’ information, VBE members public profiles, etc.</td>
</tr>
<tr>
<td><strong>Social Perspective</strong></td>
<td>Social Perspective is a Trust Perspective referring to those trustors who consider social factors as primary when assessing trustworthiness of trustee. They put more weight on issues like institutional and social concerns. Usually, the primary aim, and the basis of existence of the trustee organizations and their daily activities are important. The trustee will be evaluated depending on achievements in issues such as their participation in communities’ services, contribution to societal achievements (e.g. disabled schools), compliance to community rules/standards (e.g. environment standards), etc.</td>
</tr>
<tr>
<td><strong>Technological Perspective</strong></td>
<td>Technological Perspective is a Trust Perspective referring to those trustors who consider technological factors as primary aspect when assessing a trustee’s trustworthiness. Thus, the assessment of trustworthiness of a trustee is based on its successes and capabilities in technological issues. For example a customer (as a trustor) can use various performance measures such as network speed, interoperability, and availability to evaluate electronic transaction. For high trustworthiness level, a trustee must possess a good and required infrastructure to facilitate the cooperation or collaboration.</td>
</tr>
<tr>
<td><strong>Trust Criterion</strong></td>
<td>Trust criterion refers to the measurable elements that can establish a judgment about a given trust requirement. For example for the requirement of ICT infrastructure, the measurable trust criteria can include the storage capacity, the computing capacity, frequency of the system’s security violation, network speed, etc. Every trust criteria have two attributes for its values, namely: Trust value metrics, which refer to the scales that identify the meaning of the measured values for the criterion, (e.g. for computing capacity can be megabyte MB/s), and Trust value constraints, which refer to the limits for values that separate the acceptable from unacceptable range of values (e.g. for computing capacity can be &gt;300GB/s).</td>
</tr>
<tr>
<td><strong>Trust Objective</strong></td>
<td>Trust objective: is the purpose for which the trust relationship establishment among the involved organizations is required. Examples of trust objectives include the following: for inviting an organization to join a VO, for appointing or selecting an organization as the VO coordinator, for an organization to decide joining a VBE, etc.</td>
</tr>
<tr>
<td><strong>Trust Perspective</strong></td>
<td>Trust Perspective represents the “point of view” of a trustor on the most important aspects to be considered for assessing the trustworthiness of trustee.</td>
</tr>
<tr>
<td><strong>Trust Perspective among two members</strong></td>
<td>Trust Perspective among two members is a Trust Perspective referring to the “point of view” of a trustor (VBE member) on the most important aspects to be considered for assessing the trustworthiness of trustee (another VBE member).</td>
</tr>
<tr>
<td><strong>Trust Perspective between a Client and the VBE</strong></td>
<td>Trust Perspective between a Client and the VBE is a Trust Perspective referring to the “point of view” of a client on the most important aspects to be considered for assessing the trustworthiness of VBE.</td>
</tr>
<tr>
<td><strong>Trust Perspective between a Member and the VBE</strong></td>
<td>Trust Perspective between a Member and the VBE is a Trust Perspective referring to the “point of view” of a VBE member on the most important aspects to be considered for assessing the trustworthiness of VBE and the VBE administration.</td>
</tr>
<tr>
<td><strong>Trust Requirement</strong></td>
<td>Trust Requirements represent the essentials (cardinals) that characterize and guide on how the respective trust perspective can be realized. Thus, trust requirements are the fundamental cardinals that guide or suggest what must be met in order for</td>
</tr>
</tbody>
</table>
D.8. VBE Governance sub-ontology

The VBE Governance sub-ontology includes the knowledge concepts characterizing VBE’s rules, bylaws, principles, and collaboration culture. For example, it defines the sub-classes of “VBE Bylaw” such as “Conflict Resolution Policy” and “ICT Use Guideline”. The concepts for this sub-ontology were mainly identified in [129]. The VBE governance sub-ontology is addressed in Table D.8 below.

Table D.8: Concepts related to the VBE governance sub-ontology

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VBE Governance</strong></td>
<td>VBE Governance refers to set of norms to be followed in order to affecting government and monitoring (through policy) the long-term strategy and direction of the VBE.</td>
</tr>
<tr>
<td><strong>Amendments to Bylaw</strong></td>
<td>Amendments to Bylaw are the revisions/modifications to bylaws. Notice of proposed changes in the rules should be circulated to all VBE participants with a considerable time ahead of the meeting at which they are to be acted upon.</td>
</tr>
<tr>
<td><strong>Conflict Resolution Policy</strong></td>
<td>Conflict Resolution Policy is policy to workout emerging problems among participants during VBE activities, which are monitored by a VBE board headed by a VBE manager/administrator. The most relevant cases that could introduce conflicts to the VBE are: Breach to a contract, disclose of confidential information, use of VBE resources for interest that is external to the VBE, Intellectual Property Rights sol (in case of patents), among others.</td>
</tr>
<tr>
<td><strong>Financial Policy</strong></td>
<td>Financial Policy is a policy for payments and an accounting in order to guarantee</td>
</tr>
<tr>
<td>Concept</td>
<td>Definition</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Functional / Operational Rule</td>
<td>Functional / Operational Rules support both operational and administrative processes along all VBE lifecycle stages.</td>
</tr>
<tr>
<td>ICT Use Guideline</td>
<td>ICT Use Guidelines regulate the use of technology as a mean to disclose and share the information, respecting the policies and rules, according to the ethical and behavioural code.</td>
</tr>
<tr>
<td>Incentive</td>
<td>Incentives are positive actions referred to members and taken under a performance assessment, which is given through definition and measurement of indicators.</td>
</tr>
<tr>
<td>Membership Policy</td>
<td>Membership Policy determines the state or condition of belonging to the VBE after passing an assessment process and being qualified according to some predefined features, some (i.e.: inscription fees, % of economical benefits, etc.).</td>
</tr>
<tr>
<td>Rights and Duty Policy</td>
<td>Rights and Duty Policy defines responsibilities (rights and duties) of all VBE participants, as well as prioritization and some related functions.</td>
</tr>
<tr>
<td>Sanction</td>
<td>Sanctions are negative/punitive actions referred to members and taken under a performance assessment, which is given through definition and measurement of indicators.</td>
</tr>
<tr>
<td>Security Issue</td>
<td>Security issues are policies to safeguard the confidentiality of exchanged information and obtained knowledge that must be defined prior to operations of the VBE.</td>
</tr>
<tr>
<td>VBE Administrative Function Rule</td>
<td>VBE Administrative Function Rules are the necessary rules to govern and sustain general management and support process especially in core legal and administrative activities of VBE functioning.</td>
</tr>
<tr>
<td>VBE Behaviour</td>
<td>VBE behaviour rules mainly aim to govern social aspects in VBE operations among participants (is twofold addressed: Ethical Code, Culture).</td>
</tr>
<tr>
<td>VBE Bylaw</td>
<td>VBE Bylaws are the regulations that VBE adopts that set forth duties, limit authority and establish orderly procedures for conducting business (internal affairs).</td>
</tr>
<tr>
<td>VBE Culture</td>
<td>VBE Culture is the pattern of shared basic assumptions (converted into rules) that the VBE learned as it solved its problems of external adaptation and internal integration that has worked well enough to be considered valid and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems.</td>
</tr>
<tr>
<td>VBE Ethical Code</td>
<td>Ethical Behaviour guided by and ethical code is (accepted standards of conduct) expected from members of an organisation will determine a member’s continuity in organisation. Ethical codes are commonly defined from some important deontological values. (Attitude, no discrimination, awareness for win-win development, etc.)</td>
</tr>
<tr>
<td>VBE Principle</td>
<td>VBE Principles are the elements defined as the result of a vision, something that the VBE wants to reach (e.g.: honesty, trust and integrity, openness, performance orientation, responsibility and accountability, among others).</td>
</tr>
<tr>
<td>VBE Rule</td>
<td>Rules are policies or (set of laws) to govern activities performed within VBE (lifecycle, operational/management and behavioural related)</td>
</tr>
</tbody>
</table>

### D.9. Value System sub-ontology

The Value System sub-ontology includes the main concepts of knowledge for characterizing VBE’s system of values and capitals. For example, it defines the concept of “VBE Value System” itself, as well as the components of the Value System such as “Value Generation Objects” and “Performance Measurement System”. The specific concepts for this ontology were obtained mainly from [130]. The VBE Value System sub-ontology is addressed in Table D.9 below.
<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VBE Value System</strong></td>
<td>VBE Value System is ordering and prioritizing a set of values that an organization holds, exchanges and creates.</td>
</tr>
<tr>
<td>Brand Recognition</td>
<td>Brand Recognition is the relative perception of customers of one brand to other competitive alternatives.</td>
</tr>
<tr>
<td>Branding &amp; Marketing</td>
<td>Branding &amp; Marketing includes two definitions: branding as the process to create prestige, value and recognition for a product/service or organisation with the support of marketing, the brand can be associated with the product or service, or with the name of the organisation. And marketing as the group of coordinated activities for defining the mix of product, price, promotion and place for the commercialization of a product or service.</td>
</tr>
<tr>
<td>Capital System</td>
<td>Capital System is the inventory of capitals (value generation objects) of a determinate organisation. It is the representation of a Value System of an organisation removed in a classification of categories.</td>
</tr>
<tr>
<td>Incentive Indicator</td>
<td>Incentive Indicator reflects some benefits for different types of positive behaviours of VBE participants.</td>
</tr>
<tr>
<td>Indicator System</td>
<td>Indicator System measures different components of a Value System and provides information about how individual components work together to produce a total effect.</td>
</tr>
<tr>
<td>Integral Report of Value (IRV)</td>
<td>Integral Report of Value (IRV) is a tool for register and communicates the most representative facts of the capital system that supports the creation of value in an organisation.</td>
</tr>
<tr>
<td>Metrics</td>
<td>Metrics are standards of measurements that are used to scale and provide meaningful interpretation of quantities measured for each criterion.</td>
</tr>
<tr>
<td>Organisational Prestige</td>
<td>Organisational Prestige is the relative market recognition of high standing performance and success of an organisation.</td>
</tr>
<tr>
<td>Organisational Reputation</td>
<td>Organisational Reputation is the relative market opinion of the organisational behaviour or quality of its products/services.</td>
</tr>
<tr>
<td>Performance measurement</td>
<td>Performance measurement is the selection and use of quantitative and qualitative measures of capacities, processes, and outcomes to develop information about critical aspects of activities, including their effect on the achievement of the goals.</td>
</tr>
<tr>
<td>Sanction Indicator</td>
<td>Sanction Indicator reflects some calls for attention for different types of negative behaviours of VBE participants.</td>
</tr>
<tr>
<td>VBE Member Capital/Value(s)</td>
<td>VBE Member Capital/Value is the generation objects that represent the values and capital that each VBE member has and generate by itself (financial, human structure, innovation &amp; learning, and relational capitals).</td>
</tr>
<tr>
<td>VBE Member Financial Capital</td>
<td>VBE Member Financial Capital refers to the financial resources (e.g. cash, bank accounts, physical assets) that an organisation uses to achieve objectives. It can be also understood as any kind of representation of financial value (e.g. cash, insures, accounts) with the possibility to acquire any kind of physical assets that represents real capital (e.g. tools, equipment, inventories) acquire any kind of physical assets that represents real capital (e.g. tools, equipment, inventories).</td>
</tr>
<tr>
<td>VBE Member Human Capital</td>
<td>VBE Member Human Capital refers to the assets of knowledge (explicit or tacit) of the organisation staff useful to create value through their competences (skills, talent, capabilities &amp; knowledge). It also refers to the capacity of the staff to act in many situations to create value. This capital can be regenerated by learning and using knowledge (know-how).</td>
</tr>
<tr>
<td>VBE Member Innovation &amp; Learning Capital</td>
<td>VBE Member Innovation &amp; Learning Capital refers to the possibility to maintain the success of an organisation in a long term by developing or improving competences to increase and fortify the efficiency of the manufacturing processes or services development. Also by developing new types of relations with other organisations or by expanding or improving the range of products and services offered, including the additional value that has an organisation by possessing exclusive use of an asset or process (e.g. Intellectual Property).</td>
</tr>
</tbody>
</table>
### Concept Definition

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VBE Member Relational Capital</strong></td>
<td>VBE Member Relational Capital refers to the relations and logistic channels that an organization maintains with his clients, suppliers or other organisations (e.g. supply chain, collaborative networks, and relations in the VBE), and the value that these types of relation generates. The quality and sustainability of the alliances and relations with others organisations, and its potential to generate new collaborative opportunities in the future, generate relational value. Knowledge (know-how) that can be obtained of the relations with other organisations also generates relational value.</td>
</tr>
<tr>
<td><strong>VBE Member Structure Capital</strong></td>
<td>VBE Member Structure Capital is the knowledge that an organisation materializes, systematizes and internalizes in the form of physical resources like: information and communication technologies, production technologies, work processes, management system, and quality standards. This capital improves the efficacy and efficiency of an organisation to produce value or add value.</td>
</tr>
<tr>
<td><strong>VBE Platform Capital/Values</strong></td>
<td>VBE Platform Capital/Values represents the methodologies, ICT and supporting tools for the VBE. This platform by itself offers different types of values (financial, human infrastructure and social/cultural capitals).</td>
</tr>
<tr>
<td><strong>VBE Platform Financial Capital</strong></td>
<td>VBE Platform Financial Capital refers to the financial resources that a VBE as a Platform uses to achieve objectives (e.g. cash, insures, bank accounts, physical assets such as tools, equipment, inventories).</td>
</tr>
<tr>
<td><strong>VBE Platform Human Capital</strong></td>
<td>VBE Platform Human Capital involves VBE administrator, VO broker, VBE advisor, VBE service provider &amp; VBE ontology provider with their skills, talent, capabilities &amp; knowledge.</td>
</tr>
<tr>
<td><strong>VBE Platform Infrastructure Capital</strong></td>
<td>VBE Platform Infrastructure Capital includes the technologies (e-catalogue, value and performance measure systems, and VBE management system), methods and processes (e-brokering, trust building &amp; management, VO creation process, VBE administration) and physical resources that support the operation of a VBE.</td>
</tr>
<tr>
<td><strong>VBE Platform Social/Cultural Capital</strong></td>
<td>VBE Platform Social/Cultural Capital refers to the working and sharing principles of a VBE represented in his strategies, philosophy, culture and ethical code (e.g. rules, policies, agreements, and contracts).</td>
</tr>
<tr>
<td><strong>VBE System Capital/Values</strong></td>
<td>VBE System Capital/Values constitutes the synergy of the value generation of each one of the VBE members and the value generation of the VBE platform.</td>
</tr>
<tr>
<td><strong>VBE System Community Interaction Capital</strong></td>
<td>VBE System Community Interaction Capital refers to the VBE strategies focus on the exploitation of VBE members’ relations and logistics channels. These strategies are a response to both the changes in the market and the necessities to create competitive advantages. They aim to exploit relations as well as working &amp; sharing principles in the VBE for their VBE members to create moral responsibility, positive intentions, mutual respect and equity between the VBE members in their collaboration activities.</td>
</tr>
<tr>
<td><strong>VBE System Expert Human Capital</strong></td>
<td>VBE System Expert Human Capital is the result of sharing and combining the Human Capital competences (i.e. skills, talent, capabilities &amp; knowledge), namely the competencies of human actors involved in VBE member organizations and the VBE-self. This will lead to increasing the expert teams’ abilities to increment the VBE actors’ capacity to apply their knowledge (know-how) to common VBE objectives and thus to add value to the developed products and performed processes.</td>
</tr>
<tr>
<td><strong>VBE System Financial Capital</strong></td>
<td>VBE System Financial Capital refers to the sum of the financial capital of the VBE members and VBE platform.</td>
</tr>
<tr>
<td><strong>VBE System Integrated Infrastructure Capital</strong></td>
<td>VBE System Integrated Infrastructure Capital is the result of sharing and combining resources (e.g. human, technologic and financial resources) between VBE members to increment their capacity to develop new products or services.</td>
</tr>
</tbody>
</table>

**D.10. VBE Management System sub-ontology**

This sub-ontology includes the main concepts defining the VBE management subsystems, such as “Profile and Competency Management System”, “Agreement Negotiation Wizard”, "..."
etc. The specific concepts for this sub-ontology were obtained mainly from [131][132][133][134] and [127]. The VBE management sub-ontology is addressed in Table D.10 below.

Table D.10: Concepts related to the management system sub-ontology

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VBE Management System (VMS)</strong></td>
<td><em>The VBE management system supports and facilitates the activities needed to be performed through the VBE life cycle stages, from the creation of the VBE through the operation and evolution, and to its metamorphosis or dissolution.</em>&lt;br&gt;<em>Abbreviation: VMS</em></td>
</tr>
<tr>
<td>VMS Sub-system</td>
<td>VMS Sub-systems provide specific functionalities to the management of VBEs, e.g. VBE Membership Management System, Profile and Competency Management System, Trust Management System, etc.</td>
</tr>
<tr>
<td>VMS Service</td>
<td>VMS Service is a certain service related to a specific VMS Sub-system, e.g. the service for customization of VBE Profile models or the service for editing of profile data, a part of the functionality of the Profile and Competency Management System.</td>
</tr>
<tr>
<td>VO Creation tool</td>
<td>VO Creation tools aim at supporting the VO Broker, VO Planner, and the potential VO Partners through the entire VO creation process. These tools are integrated to the VMS as its fundamental component. Example of such tools include: the Collaborative Opportunity Finder tool, the Collaborative Opportunity Characterisation and VO Rough Planning tool, the Partner Search and Suggestion tool, and the Negotiation Wizard tool.</td>
</tr>
</tbody>
</table>
Annex E

Example sub-ontologies for domain levels of VBE-ontology

This Annex addresses two example domain level sub-ontologies developed for the manufacturing domain, namely (1) the sub-ontology for automatic machining processes and (2) the sub-ontology for manufacturing practices.

The automatic machining process sub-ontology is a domain level sub-ontology developed as a population of the “Process” concept from the core level VBE profile and competency sub-ontology into the automatic machining domain of activities. This sub-ontology was specified by the Swiss Microtech VBE. Its terms and definitions were identified by the domain experts working for this VBE. This sub-ontology is intended to be used in the Profile and Competency Management System (as addressed in Chapter 4 of this thesis) for categorization and analyzing of business processes definitions. This ontology is reusable by various VBEs operating in the automatic machining domain.

- “Automated machining”
  Definition: Turn, shape, mould, or otherwise finish process performed by machinery.

- “Drilling”
  Definition: Making a hole, especially with a pointed power or hand tool.
  Subclasses: “Angular drilling” (is not presented), “Axial drilling” (is not presented), “Radial drilling (is not presented)

- “Forming”
  Definition: Giving shape or form to an object.
  Subclasses: “Knurling” (is not presented), “Marking” (is not presented), “Rolling” (is not presented)

- “Gear milling”
  Definition: Milling using gears.
  Subclasses: “Axial gear milling” (is not presented), “Conical gear milling” (is not presented), “Radial gear milling” (is not presented)

- “Grinding”
  Definition: Reduce to small pieces or particles by pounding or abrading.
  Subclasses: “Axial grinding” (is not presented), “Flat grinding” (is not presented), “Radial grinding” (is not presented), “Thread grinding” (is not presented)

- “Milling”
  Definition: Producing a ridge around the edge of an object.
  Subclasses: “Complex forms milling” (is not presented), “Flat milling” (is not presented), “Simple forms milling” (is not presented), “Slot milling” (is not presented), “Very complex forms milling” (is not presented)

The manufacturing practice sub-ontology is a domain level sub-ontology developed as a population of the “Practice” concept from the core level VBE profile and competency sub-ontology into the manufacturing domain. This ontology was provided by the IECOS VBE. Its terms and definitions were identified by the domain experts working for this VBE. This sub-ontology is intended to be used in the Profile and Competency Management System.
for categorization and analyzing of practices definitions. It is also reusable by various VBEs operating in the manufacturing domain.

- **“Manufacturing practice”**
  
  *Definition:* Techniques, technologies and standards used for manufacturing
  

- **“Computer-aided design”**
  
  *Definition:* Computer-aided design (CAD) is the use of computer technology to aid in the design and especially the drafting (technical drawing and engineering drawing) of a part or product, including entire buildings. It is both a visual (or drawing) and symbol-based method of communication whose conventions are particular to a specific technical field.
  
  *Abbreviation:* CAD

- **“Computer-aided engineering”**
  
  *Definition:* Computer-aided engineering (CAE) is the use of information technology for supporting engineers in tasks such as analysis, simulation, design, manufacture, planning, diagnosis and repair.
  
  *Abbreviation:* CAE

- **“Computer-aided manufacturing”**
  
  *Definition:* Computer-aided manufacturing (CAM) is the use of computer-based software tools that assist engineers and machinists in manufacturing or prototyping product components. CAM is a programming tool that allows you to manufacture physical models using computer-aided design (CAD) programs. CAM creates real life versions of components designed within a software package.
  
  *Abbreviation:* CAM
  
  *Subclasses:* “Rapid Prototyping”

- **“Rapid Prototyping”**
  
  *Definition:* Rapid prototyping is the automatic construction of physical objects using solid freeform fabrication.
Annex F

Example profile and competency

Tables F.1 and F.2 addressed below represent examples profile and competency definitions filled in for a VBE member organization from the IECOS VBE [84] in Mexico. These definitions are constructed based on the generic profile and competency models addressed in Section 3.3. Particularly, they represent a proof of validity of these models.

When a new collaborative / business opportunity emerges through a call for tenders, an opportunity broker can match this profile / competency description against the characterization and criteria specified in the call for tenders.

Please note that some confidential information in these definitions is replaced by fake data, for example the name of the VBE members is replaced with “Enterprise A1”, while some other information is replaced with a set of “x” symbols

F.1. Example of a profile

This Section in Table F.1 addresses an example profile of a VBE member organization. This profile is constructed according to the generic profile model addressed in Chapter 3, Section 3.3.1.

Table F.1: Example of a VBE member organization’s profile

<table>
<thead>
<tr>
<th>VBE independent-information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic information</strong></td>
</tr>
<tr>
<td>Name</td>
</tr>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Description</td>
</tr>
<tr>
<td>Primary activity</td>
</tr>
<tr>
<td><strong>Legal information</strong></td>
</tr>
<tr>
<td>Legal status</td>
</tr>
<tr>
<td>Legal address</td>
</tr>
<tr>
<td>Legal name</td>
</tr>
<tr>
<td>Creation date</td>
</tr>
<tr>
<td><strong>Mission information</strong></td>
</tr>
<tr>
<td>Mission</td>
</tr>
<tr>
<td>Vision</td>
</tr>
<tr>
<td><strong>Contact information</strong></td>
</tr>
<tr>
<td>Legal address</td>
</tr>
<tr>
<td>Contact persons</td>
</tr>
<tr>
<td><strong>Financial information</strong></td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>Total sales last year</td>
</tr>
<tr>
<td>Total revenue last year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Competency information</strong></th>
<th></th>
</tr>
</thead>
</table>
| Competency                  | Competency 1: *(see Table F.2 below)*  
|                             | Competency 2:  
|                             | … |

<table>
<thead>
<tr>
<th><strong>Resource</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Human resource 1:</td>
<td></td>
</tr>
</tbody>
</table>
| Class: Mechanical Engineers  
| Description: Production planning and scheduling  
| Quantity: 1  
| Human resource 2:         |  
| IT resource 1:            |  
| Class: software > MasterCAM  
| Description: Offline programming of CNC machines  
| IT resource 2:            |  
| Physical resource 1:      |  
| Class: machinery > MILLER Model 200  
| Description: Welding Machine for a steel joining process  
| Quantity: 2  
| Physical resource 2:      |  
| … | |

<table>
<thead>
<tr>
<th><strong>Associated partner information</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Partner 1:</td>
<td></td>
</tr>
<tr>
<td>Name: Enterprise B1</td>
<td></td>
</tr>
<tr>
<td>Relationship: supplier</td>
<td></td>
</tr>
<tr>
<td>Duration: since 2003</td>
<td></td>
</tr>
<tr>
<td>Partner 2:</td>
<td></td>
</tr>
<tr>
<td>…</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>VBE-dependent information</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VBE registration information</td>
<td></td>
</tr>
<tr>
<td>Registration ID</td>
<td>xxx</td>
</tr>
<tr>
<td>Participation role</td>
<td>VBE member organization</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>VBE history information</strong></th>
<th></th>
</tr>
</thead>
</table>
| Collaboration history       | VO-1:  
| Name: XXX  
| Description: XXX |

<table>
<thead>
<tr>
<th><strong>Evidence document</strong></th>
<th></th>
</tr>
</thead>
</table>
| Authorized / certified evidence | Certificate 1:  
| Description: Quality Standard Certification ISO 9001:2000  
| Date of issue: 2005  
| License 1:  
| … |
| Whiteness evidence      | Letter of recommendation 1:  
| … |
F.2. Example of a competency

Please note that Table F.2 below addresses the example for a VBE member organization’s competency that is a part of the profile addressed in Table F.1. This competency description is constructed according to the generic 4C8-model of competency addressed in Section 3.3.2.

Table F.2: Example of a VBE member organization’s competency

<table>
<thead>
<tr>
<th>Competency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class: Metalworking</td>
</tr>
<tr>
<td>Description: Metalworking with focus on Machining and Stamping of high quality manufacturing pieces.</td>
</tr>
</tbody>
</table>

**Capability**

**Capability 1:**
- **Class:** Turning
- **Description:** Mechanical Reducing
- **Capacity:** Resource capacity 1
- **Product:** Product 1
- **Cost:** Cost 1

**Capability 2:**
- **Class:** Deep Drawing
- **Description:** Deformation
- **Capacity:** Resource capacity 2
- **Product:** Product 1
- **Cost:** Cost 2

**Capability 3:** ...

<table>
<thead>
<tr>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product 1: goods</td>
</tr>
<tr>
<td>Description: Machined products for thermal systems industry</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource capacity 1:</td>
</tr>
<tr>
<td><strong>Resource:</strong> Human resource 1, Physical resource 2</td>
</tr>
<tr>
<td><strong>Measure:</strong> % per day</td>
</tr>
<tr>
<td><strong>Rate:</strong> 50</td>
</tr>
<tr>
<td><strong>Conspicuity:</strong> Certificate 1</td>
</tr>
<tr>
<td>Resource capacity 2: ...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conspicuity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fact-based conspicuity:</strong> Certificate 1:</td>
</tr>
<tr>
<td><strong>Class:</strong> Certificate</td>
</tr>
<tr>
<td><strong>Issuer:</strong> ISO</td>
</tr>
<tr>
<td><strong>Document ID:</strong> xx</td>
</tr>
<tr>
<td><strong>Title:</strong> Quality Standard Certification ISO 9001:2000</td>
</tr>
<tr>
<td><strong>Validity period:</strong> unlimited</td>
</tr>
<tr>
<td><strong>License 1:</strong> ...</td>
</tr>
<tr>
<td><strong>Opinion-based conspicuity:</strong> Letter of recommendation 1: ...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost 1:</td>
</tr>
<tr>
<td><strong>Cost-item:</strong> Day turning</td>
</tr>
<tr>
<td><strong>Cost-value:</strong> $ xxx</td>
</tr>
<tr>
<td><strong>Conspicuity:</strong> License 1</td>
</tr>
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Annex G

**Author’s publications**

The following is the list of publications achieved by the author of this book which provided relevant contribution to the content of this dissertation. The publications are classified into four groups G1, G2, G3, and G4 on the basis of the four main subjects addressed in this thesis as presented in Chapter 5, Section 5.3.3.

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Technical project reports

1. Virtual Collaborative networks supporting LifeWatch R&D infrastructure in biodiversity domain, 5.2.a, LIFEWATCH project, June 2009


3. VBE instantiation methodology, D21.5, ECOLEAD project, 2008

4. 2nd Prototype of the advanced support tools, methods and services for VMS: PCMS, ODMS, and TrustMan systems, D22.4b (Part I), ECOLEAD project, October 2007

5. A reference model for Collaborative Networks, D52.3, ECOLEAD project, April 2007

6. 1st prototype of the advanced support tools, methods and services for VMS: PCMS, ODMS, and TrustMan system, D22.4a (Part I), ECOLEAD project, March 2007


8. Rough reference model for Collaborative Networks, D52.2, ECOLEAD project, March 2006


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[134] 2nd Prototype of the advanced support tools, methods and services for VMS: PCMS, ODMS, and TrustMan systems, D22.4b (Part I), ECOLEAD project, October 2007
Acknowledgments

Since I came to the University of Amsterdam in December 2004, I was always thinking what I would write in this section. It always seemed to be very difficult to write it concise, but still mention everyone who helped me to come to this stage of my PhD research.

First of all, I would like to thank my PhD thesis supervisor and promoter prof. dr. Hamideh Afsarmanesh for giving me an opportunity to do a PhD in her research group at UvA, and trusting me to participate in the large European project ECOLEAD.

The ECOLEAD project was one of the most exciting experiences in my life. In this project, which lasted for four years, I worked with people from more than ten different countries and from more than twenty different organizations, both academy and business, in Europe and Latin America. I miss our meeting, discussions, city trips, and dinners, my dear former ECOLEAD colleagues from Portugal, Mexico, Germany, Czech Republic, Slovenia, France, and Brazil, especially David Romero, Ana Ines Oliveira, and Filipa Ferrada. I am very thankful to prof. dr. Luis Camarinha-Matos from the University of Lisbon for providing unique professional opportunities within the ECOLEAD project and the SOCOLNET society, and to Michael Pouli and Jean Beeler from Swiss Microtech AG who let me see how my research works in practice.

The FCN group of Hamideh has been always known as very hard-working. Hamideh has been doing her best to bring her group members to her level of professionalism, for example to be able to write a journal paper in one week, or to review three conference papers in one day. But something that seemed to me enormously hard in 2005, is very easy now, and I am thankful to Hamideh for her effort. Hamideh is also one of not many supervisors who read, commented, and helped to improve every single sentence in her students’ research papers, helping to bring the scientific writing skills to a high-quality level.

My closest colleague in the FCN group was Simon Msanjila, who is by now a professor in Tanzania. Dear Simon, thanks for your wisdom and for your support during the five years we shared the same office. My other FCN colleagues, Jafar Tanha, Naser Ayat, Elinor Bakker, and Miriam Ghijsen, thank you for your help in our daily FCN activities, and well for inspiration in some important decision making.

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Finally, it is time to mention my Russian roots and my family. I was very lucky to get a very good education in my home town Pereslavl-Zalessky, Russia. I am thankful to all teachers and lecturers who were working at the Pereslavl Gymnasium, Pereslavl University, and the Program Systems institute at that time, and especially to prof. dr. Sergey Abramov and dr. Valeria Yumaguzhina.

I also thank my family, and especially my mother Antonina Ermilova and my cousin Elena Daniulova, for their support and patience. Мама, Лена, я вас очень люблю. Спасибо вам за все!
Abstract

To create more chances for capturing new opportunities in the market and society, organizations and in particular small and medium enterprises (SMEs) increasingly move toward collaboration with each other, through reaching larger set of competencies and resource capacities. The so-called Virtual Organizations (VOs) are then formed among autonomous organizations that are typically heterogeneous, autonomous, and geographically distributed. VOs are goal-oriented consortia, and typically dissolve after achieving their goals.

With the purpose of optimising and facilitating effective / agile creation of VOs, in recent decades both research and practice have shown interest in pre-establishing a longer-term network / alliance of SMEs to serve as the base. Thus, the so-called Virtual organisations Breeding Environments (VBEs) are established for this purpose in a variety of domains, from manufacturing to elderly care, providing the common platform for SMEs to join, in order to prepare themselves for collaboration and reaching the level of readiness needed for effective formation of VOs.

VBEs can appear in different sizes and may reach thousands of geographically distributed members, willing to collaborate within VOs, and sharing their profits and losses, through the effective use of their combined competencies, capabilities, capacities and know how. Management of the VBEs is challenging, and in need of designing better or new approaches and tools. Specifically, it is challenging to properly support: managing the operations of VBEs, supervising VBE members’ activities, preparing VBE members for collaborating, facilitating VO brokers once they find and/or define an opportunity, as well as enabling agile / fluid formation of VOs composed of VBE members. During its life cycle, every VBE handles large varieties of data, information, and knowledge. However, the information and knowledge accumulated in VBEs should be commonly understood by all its stakeholders, and properly formatted and stored so that it can be effectively processed and analysed. Therefore, as a main element of the VBE management, advanced management of its information is required, as addressed by the research of this thesis.

Our research is focused on the design and development of an information management approach and system for the 2nd generation Virtual organisations Breeding Environments (VBEs). It addresses many of the challenges related to the creation of VBEs and their effective operation. As such, it first addresses the existing background of this area, the so-called 1st generation VBEs. It then identifies a set of problem areas and open questions to be targeted by our research. It especially introduces four high-level research challenges related to creation and operation of 2nd generation VBEs, including:

(i) Facilitating the common understanding of environmental concepts - Although 1st generation VBEs run for a few decades in some industries and specifically in manufacturing, there is still lack of generally accepted definitions for the generic VBE concepts. This in turn causes the lack of common understanding and effective communication of concepts among the VBE members. In practice, this problem becomes even more severe due to both the need for merging and interrelation of different types of generic concepts within the VBE, and the continuous and dynamic joining of new members/actors to the VBE, each bringing their own bag of new domain-dependent knowledge and terminology.

(ii) Effective assistance with the VBE instantiation in different sectors and domains - Every VBE instantiation case is costly and quite time/effort consuming. This is mostly due to the fact that every VBE at its creation step should establish, among others, a common ICT platform and infrastructure for its members’ co-
working, specific set of working and sharing principles, and a set of advanced functionality for management and supervision of its members and their activities, etc., in order to perform its own supporting managerial activities, e.g. finding potential market opportunities for formation of VOs, and selection of the most fit group of partners for a VO, which are not straightforward.

(iii) Supporting the required dynamism and scalability of VBEs – In order to capture emerging opportunities in volatile markets, VBEs shall act dynamic and adaptive. This means also being open to continuously extending/adapting their membership and size, and customization and parameterization of functionality to match the specific emerged needs. Furthermore, the VBE administrator requires access to most up to date competency, capacity, etc. information related to both new and existing members. Developing semi-automated ICT-supported approaches and functionalities are required to adapt and facilitate these dynamic processes.

(iv) Boosting and balancing the involvement of VBE members in the VOs – Both the variety in kinds of information as well as the dynamism in features and abilities that represent each organization at the VBE, pose obstacles to acquiring such updated information for the purpose of organization’s involvement in potential VOs. In small running VBEs, the VBE administrator might remember and be unofficially informed about all its members. But in the 2nd generation VBEs, the large size of the VBE adds further complexity to the above point, which further prevents VBEs from being able to provide fair chances for VO involvement to VBE organizations.

The approach and methodologies introduced in this thesis focus on tackling the above four challenges. It specifically first addresses the development and management of the VBE ontology, and second the expansion of one of its sub-ontologies, focused on organizations profile and competency. These elements are then implemented as two of the main components of the VBE management system.

The developed VBE-ontology addresses the challenge (i) above through defining the comprehensive set of VBE concepts, so that it can be shared in a uniform format, and commonly understood by the variety of VBE stakeholders. The VBE-ontology responds to the challenge (ii) above through serving as the common data model for development of distinct VBE databases in different sector/application, and specifically to be used for specification of VBE data classification, and parameterisation of VBE management tools. Furthermore, the VBE-ontology responds to the challenge (iii) above through provision of semantics, that can support semi-automated acquiring and management of VBE information, and in turn accelerating the information management processes of the VBEs. Finally, the VBE-ontology responds to the challenge (iv) above by providing means for formal and uniform representation of characteristic information related to the VBE members, such as their profiles and competencies, which can in turn support the balanced involvement of all its involved organisations in potential VOs. Furthermore, in order to comprehensively address the above challenges with ICT-based supporting tools, the thesis introduces and implements a system called the ColOnto (Collaborative networks Ontology) system, built on top of the VBE-ontology. As such, while the conceptual part of the ColOnto system represents the specification of the VBE-ontology itself, it functional part is composed of the set of functionalities that support the maintenance and management of the VBE-ontology.

The main contributions of this thesis are therefore twofold:

- The methodology applied for design and engineering of a unified ontology for VBEs, called the VBE-ontology is described. The VBE-ontology is specified. Furthermore, among the several partitions defined as sub-ontologies of the VBE-ontology, one main partition dedicated to the profiles and competencies of VBE member organisations, is detailed out and specified.
• An information management system and a set of specific functionalities to tackle the VBE-ontology are designed and developed. This system, called the Ontology Discovery and Management System (ODMS) introduces specific services to help both the VBE members in familiarising themselves with the VBE concepts, as well as the VBE administrator with management of operations and parameterising different VBE management sub-systems. One main component of the ODMS is another system called the VBE Profile and Competency Management System (PCMS). The PCMS in turn introduces the set of functionalities required for management of the profiles and competencies of different VBE actors.

Besides storage and viewing the ontology concepts, several other functionalities are implemented in the prototype of the ODMS, including: ontology modification, concept search, ontology-based text-mining, etc. Similarly, the prototype for the PCMS represents functionalities for storage and manipulation of both the VBE’s profile and competency models and related information content, further to searching competencies and extraction of VBE’s aggregated competencies, among others.

All our developments, i.e. the theoretical framework, the methodologies, and the prototypes, presented in the thesis, have gone through direct validation / evaluation procedure within the operational environments of four different running VBEs, and have generated positive results and better performance than alternative systems.

The work in this thesis is partially achieved within the context of the EC-funded integrated research project ECOLEAD, within which this research and its development and validation are achieved. Most concepts introduced in this thesis and its produced results are already published and presented to the research community, through several technical channels.
Samenvatting

Om meer mogelijkheden te creëren voor het benutten van de nieuwe kansen op de markt en in de maatschappij, gaan organisaties, en met name middelgrote en kleine bedrijven (MKB's), in toenemende mate samenwerking met elkaar aan. Hiermee breiden ze hun competenties en capaciteiten uit. Er worden zogenaamde Virtuele Organisaties (VO's) gevormd uit organisaties, die typisch heterogeen, autonoom en geografisch verspreid zijn. VO's zijn doelgericht consortia, die meestal weer worden ontbonden na het bereiken van hun doelen. In de afgelopen decennia hebben zowel onderzoek als bedrijfsleven interesse getoond in het opzetten van langere-termijn netwerken en allianties van MKB's die als de basis kunnen dienen voor VO's. Zogenaamde Virtuele organisaties Genererende Omgevingen (VGOs) zijn opgericht in verschillende domeinen, van productie tot ouderenzorg. Dit biedt een gemeenschappelijk platform voor MKB's om zich te verenigen en voor te bereiden op samenwerking en daarbij een niveau te bereiken dat nodig is voor het opzetten van effectieve VO's.

VGO's kunnen verschillen in grootte en uit duizenden geografisch verspreide leden bestaan. De leden willen samenwerken binnen VO's om hun winsten en verliezen te delen en effectief gebruik te maken van hun gecombineerde competenties, mogelijkheden, capaciteiten en kennis. Het beheer van de VGO's is uitdagend, en heeft behoefte aan betere of nieuwe benaderingen en instrumenten. In het bijzonder, is het uitdagend om de volgende aspecten van VGO goed te ondersteunen: het beheer van de activiteiten van VGO's, het toezicht op de activiteiten van VGO leden, het voorbereiden van VGO leden voor de samewerking, het faciliteren van VO brokers wanneer zij nieuwe mogelijkheden identificeren en het ondersteunen van soepere vorming van VO's uit VGO leden. Tijdens haar levenscyclus verwerkt elke VGO grote hoeveelheden data, informatie en kennis. Toch moeten alle belanghebbenden van de organisatie een goed begrip hebben van de opgebouwde informatie en kennis. Deze informatie moet goed worden gestructureerd en opgeslagen, voor effective analyse en verwerking. Daarom is het geavanceerde beheer van deze informatie een belangrijk en noodzakelijk element van VGO beheer. Dit aspect staat centraal in dit proefschrift.

Het onderzoek richt zich op het ontwerp en de ontwikkeling van een informatie beheer systeem voor de tweede generatie van Virtuele organisaties Gegenenererend Omgevingen (VGO's). Het behandelt veel kwesties in verband met het samenstellen van VGO's en hun effectiviteit. Ten eerste, wordt de achtergrond van dit onderwerp behandeld, de zogenaamde eerste generatie VGO's. Vervolgens, worden er probleem gebieden geïdentificeerd en open vragen gedefinieerd die worden beantwoord in dit onderzoek. Er worden vier algemene uitdagingen gedefinieerd met betrekking tot oprichting en functioneren van 2e generatie VGO's, namelijk:

(i) Het verduidelijken van het algemene concept VGO - Hoewel eerste generatie VGO's al een paar decennia functioneren in een aantal industriële sectoren, en in het bijzonder in de productie, zijn er nog steeds geen algemeen erkende definities voor de generieke VGO concepten. Dit veroorzaakt een problemen bij begrip en effectieve communicatie tussen de VGO leden. In de praktijk, wordt dit probleem nog erger door de noodzaak van het samenvoegen aan elkaar relateren van generieke concepten binnen de VGO en de continue en dynamische toevoeging van nieuwe VGO leden waarbij elk lid eigen domein-afhankelijke kennis en terminologie meebrengt.

(ii) Effectieve hulp bij het opzetten van een VGO in verschillende sectoren en domeinen – Het process van het opzetten van VGO is duur en kost veel tijd en moeite. Dit komt voornamelijk doordat voor elke VGO in de beginfase een gemeenschappelijk ICT-platform en infrastructuur opgezet moet worden voor de samenwerking van zijn
leden. Daarnaast moeten een specifieke set van werk principes, en een set van geavanceerde functies voor het beheer en toezicht op de leden en hun activiteiten ontwikkeld worden. Dit maakt ondersteunende en leidinggevende activiteiten mogelijk, bijvoorbeeld het vinden van potentiële marktkansen om VO’s te vormen, en de selectie van de meest geschikte groep van partners voor een VO.

(iii) Ondersteuning van de gewenste dynamiek en schaalbaarheid van VGOs - Om nieuwe kansen in de volatiele markten te benutten, moeten de VGOs zich dynamisch en adaptief opstellen. Dit betekent ook openstaan voor de continue uitbreiding van hun samenstelling en grootte, en aanpassing en parametrisering van functionaliteiten om aan de specifieke behoeften te kunnen voldoen. Bovendien heeft de VGO beheerder toegang nodig tot de meest up-to-date informatie over competentie, capaciteit en dergelijke leden en mogelijke nieuwe leden. Het ontwikkelen van semi-geautomatiseerde ICT-ondersteunde oplossingen en functionaliteiten is nodig om de dynamische processen aan te passen en te faciliteren.

Het stimuleren en het balanceren van de betrokkenheid van de VGO-leden in het VO - De variëteit in soorten informatie en de dynamiek in functies en mogelijkheden, die kenmerkend zijn voor elke organisatie in de VGO, vormen belemmeringen voor het verwerven van informatie die nodig is voor de participatie van de organisatie in potentiële VOs. In kleine VGOs is informele communicatie en opslag van informatie voldoende, maar in 2e generatie VGOs draagt de grote omvang van de VGO bij aan de complexiteit. Dit vermindert de kanssen voor VO om mee te doen aan de VGO organisaties.

De methodieken, die in dit proefschrift worden voorgesteld, richten zich op de aanpak van de vier bovengenoemde uitdagingen. Ten eerste wordt de ontwikkeling en het beheer van de VGO-ontologie behandeld. Ten tweede wordt de uitbreiding van een van de VGO sub-ontologieën uitgewerkt, die gericht is op profielen en competenties van VGO-leden. Deze elementen worden dan geïmplementeerd als twee van de belangrijkste onderdelen van het VGO beheersysteem.

De ontwikkelde VGO-ontologie pakt de bovengenoemde uitdaging aan (i) door de definitie van VGO concepten, zodat deze gedeeld kunnen worden in een uniform formaat tussen de verschillende VGO leden. De VGO-ontologie adreseert uitdaging (ii) door het voorstellen van een gemeenschappelijk datamodel voor de ontwikkeling van verschillende VGO databanken in de verschillende sectoren/applicaties. Dit model wordt gebruikt voor de specificatie van VGO data classificatie en parametrisering van VGO beheersystemen. Bovendien, draagt de VGO-ontologie bij aan het oplossen van (iii) door het leveren van semantiek, die semi-automatische verwerving en het beheer van VGO informatie ondersteunt en daarmee de informatie management processen van de VGOs versnelt. Tenslotte, adreseert de VGO-ontologie uitdaging (iv) door het voorzien van formele en uniforme representatie van kenmerkende informatie over de VGO leden. Deze informatie bevat de profielen en competenties en ondersteunt daarmee de evenwichtige betrokkenheid van alle VGO leden in potentiële VO’s. Bovendien, wordt er een systeem, genoemd ColOnto (Collaborative netwerken Ontologie), geïntroduceerd en geïmplementeerd dat het functioneren van VGOs ondersteunt Dit systeem is gebaseerd op de VGO-ontologie. Terwijl de conceptuele deel van het ColOnto systeem de specificatie van de VGO-ontologie representeert, bestaat het functionele deel uit een set van functionaliteiten die het onderhoud en beheer van de VGO-ontologie ondersteunen.

De belangrijkste bijdrage van dit proefschrift is dan ook tweeledig:

- De methodologie voor het ontwerpen van een uniforme ontologie voor VGOs, de VGO-ontologie, is beschreven. Bovendien, onder de verschillende sub-ontologieën van
de VGO-ontologie, wordt een hoofd-ontologie gedefinieerd. Deze ontologie beschrijft de profielen en competenties van VGO lidorganisaties.

- Een informatie beheer systeem en een set van specifieke functionaliteiten voor de VGO-ontologie zijn ontworpen en ontwikkeld. Dit systeem, het Ontologie Ontdekking en Beheer Systeem (OOBS), introduceert specifieke functionaliteiten om de VGO leden vertrouwd maken met de VGO concepten en de VGO beheerder te helpen met het beheren van de activiteiten en het parametriseren van verschillende VGO beheer subsystemen. Een van de belangrijkste componenten van het OOBS is een andere systeem, het VGO Profiel en Competentie Beheer Systeem (PCBS). Het PCBS introduceert functionaliteit die nodig is voor het beheer van de profielen en competenties van de verschillende VGO leden.

Naast het opslaan en bekijken van de ontologie concepten zijn er verschillende andere functionaliteiten geïmplementeerd in het prototype van de OOBS, bijvoorbeeld ontologie modificatie, concept zoeken, ontologie-gebaseerde text mining. Het prototype van de PCBS bevat functionaliteit voor het opslaan en manipuleren van de modellen van de profielen en competentie van VGO’s en van de gerelateerde data, om te zoeken op (geaggregeerde) competenties van VGO’s.

Alle voorgestelde ontwerpen in dit proefschrift, het theoretische raamwerk, de methoden en de prototypes, zijn direct gevalideerd en geevalueerd binnen de operationele omgevingen van vier verschillende bestaande VGOs, en hebben positieve resultaten en betere prestaties dan alternatieve systemen laten zien.

Het werk beschreven in dit proefschrift is gedeeltelijk uitgevoerd in het kader van het door EC gefinancierde onderzoeksproject ECOLEAD, waarbinnen dit onderzoek en de ontwikkeling en validatie werden gedaan.