Modeling and management of profiles and competencies in VBEs

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Abstract Virtual organization Breeding Environments (VBEs) are long-term clusters/associations of autonomous and geographically dispersed organizations in the market and society. The VBE aims to prepare its member organizations and enhance their readiness for potential involvement in opportunity-based Virtual Organizations (VOs). Organizing/management of profiles is a key activity in VBEs. The need for management of profiles is even larger in medium-size and large-size VBEs (e.g. with more then 50 members), where typically the member organizations do not have the chance of getting to know all others directly. Furthermore, uniform structuring/modeling of the mostly textual content of profiles enables their processing by the software that supports variety of VBE functionality. An important element of the profiles in VBEs is the *competency*. There is no consensus on the definition of competency and the existing literature associate it with a range of tangible characteristics such as resources and products, as well as intangible characteristics such as knowledge and motivation. This paper introduces and details a *unified/generic model* for VBE profiles and VBE competencies. It further addresses the design of an *adaptable, replicable and sustainable* Profile and Competency Management System (PCMS), which is being developed supported by the *ontology* for profiles and competencies. An approach and mechanism for *semi-automated* derivation/discovery of elements for organization's profile and competency from on-line text corpora is also introduced.

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Introduction

To enhance their survivability in the market/society on one hand, and to increase their profit on the other hand, organizations are now increasingly interested in collaboration with others and in forming Virtual Organizations (VOs) (Camarinha-Matos, Afsarmanesh, & Ollus, 2005). To support this emerging tendency, long term alliances are being established among organizations, to serve as the base environments for creation of VOs.

In this paper, we apply the following definitions for *VOs, VBEs, VBE organizations*, and the *VBE member organizations*.

A Virtual Organization (VO) is defined as an association/cluster/network of (legally) independent organizations (VO Partners) that come together and share resources and skills to achieve a common goal, such as preparing a proposal (or a bid), or jointly performing the tasks needed to satisfy a market/society opportunity (Camarinha-Matos & Afsarmanesh, 2006).

Some earlier approaches, have suggested the possibility of dynamic on-demand creation of VOs formed out of the open universe of organizations, e.g. accessible through the web. Both research and practice have however concluded that the most efficient manner to dynamically create VOs is through the pre-existence of a suitable VO Breeding Environment.

A *Virtual organization Breeding Environment (VBE)* is defined as an association/cluster/network of organizations (VBE members) 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 their preparedness towards collaboration in potential Virtual Organizations (Afsarmanesh & Camarinha-Matos, 2005).

VBE organizations are those registered at the VBE. The majority of organizations joins the VBE to increase their chance of VO involvement, and is traditionally bound to a specific sector. Typically, VBE organizations include: (a) profit (business-oriented) entities that provide products and services to the market/society and get involved in the VOs to gain quantitative benefits, (b) non-profit institutions, e.g. universities, NGOs, environmental support organizations, etc. that get involved in the VOs to gain qualitative benefits, (c) support institutions, for example: the legal and contractual service providers, companies supporting life maintenance for organization employees (e.g. insurance and training companies), ministries, sector associations, chambers of commerce, etc. that get involved in the VBE to gain quantitative or qualitative benefits through providing their services to the VBE member organizations, and finally, (d) customer/client organizations that may occasionally wish to become a part of the VBE and to establish a long term relationship with it and its members (Afsarmanesh & Camarinha-Matos, 2005). In this paper we refer to VBE organizations of type (a) and (b) above as *VBE member organizations*.

Aiming to facilitate and enable the creation of VOs, the VBEs shall organize and manage both the repository of profiles/competencies of VBE member organizations as well as the required capabilities, capacities, and other characteristics of the demands (e.g. call for tenders) emerging in the target environment. Furthermore, due to the continuous changes in the market/society, in order to better match against the emerging opportunities, both the VBE member organizations and the VBE itself need to *continuously evolve* and tune their aims, strategies, and competencies. Therefore, VBE member organizations are frequently subjected to updating their capabilities and other competency related characteristics for which they need to be assisted. Simultaneously, the VBE shall be equipped to manage dynamically changing profiles/competencies of its member organizations.

For the purpose of automated matching against the requirements of emerged opportunities (e.g. a call for tender in the market), modeling and management of profiles/competencies of the VBE member organizations is challenging. Furthermore, it is desired to develop approaches and tools to as much as possible semi-automate the process of updating competencies of VBE member organizations and their management functionality. Namely, on one hand in order to automate the collection/derivation of updates from the VBE member organizations, in order to decrease and if possible remove the burden of time/effort spent by the VBE member organizations for such frequent updates. And on the other hand, in order to develop the required functionality for

automated selection as well as automated categorization of profile/competency elements in the VBE.

Our approach to develop a unified/generic model for VBE profiles/competencies addresses these two concepts in details, and classifies them into two main categories of: (1) *organizations involved in the VBE* (based on the role their profile/competency plays in the VBE), and (2) the *networks involved in the VBE*, as represented in Fig. 1 below.

Furthermore, the main types of *VBE organizations* consist of: (1) the *VBE member organizations* that aim to get involved and cooperate in VOs, (2) the *VBE support providing organizations* that provide services, tools, ontology, etc. supporting different activities inside the VBE (e.g. the training or insurance organizations), and (3) the *VBE customer organizations* that may occasionally wish to get involved inside the VBE and establish close links with it. Clearly, as explained in (Afsarmanesh & Camarinha-Matos, 2005) a variety of roles can be even simultaneously assumed by the VBE members organizations, e.g. the VO broker, the VO planner, the VO coordinator, the VBE administrator, etc., depending on the configuration and aim/strategy of each VBE.

Also two types of *VBE networks* are distinguished in our unified/generic model, namely: (1) the *VBE-self network* (with only one instance) that addresses the VBE network itself as one entity, and (2) the *VO-self network* that represents the VOs created inside the VBE. Here every VO network is represented as one entity constituting all of its partner organizations.

Both the *VBE networks* and the *VBE organizations* represent *VBE entities*. The *hierarchy of VBE entities* is illustrated by the UML diagram in Fig. 1.

The generic model for VBE profiles/competencies addresses these VBE entities. The following sub-sections provide an introduction to: the *VBE profiles* in section "VBE profiles", to the *VBE competencies* in section "VBE competencies", and to the *VBE Profile and Competency Management System (PCMS)* in section "Profile and competency management system". In each of these sub-sections the *motivation,* as well as the *main challenges* for the work are introduced. The main objective of this paper is to address these identified research challenges through the unified/generic model and our proposed approach and mechanisms for management of the profiles/competencies in the VBEs.

VBE profiles

The *VBE profiles* provide structured descriptions (of mostly textual content) about the VBE entities, addressing their qualifications, and the records of their related past activities and achievements.

To support proper operation of the VBEs and their needed functionality, e.g. fluid configuration and creation of VOs, as well as for proper cooperation among the VBE members,
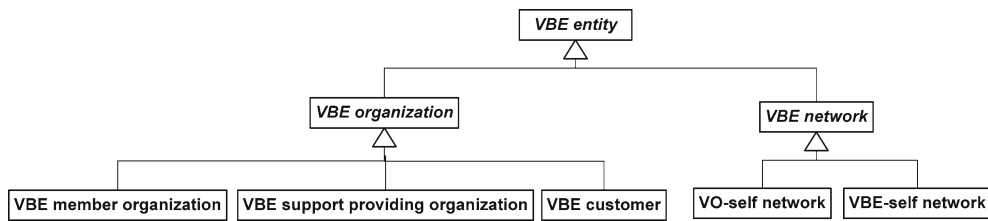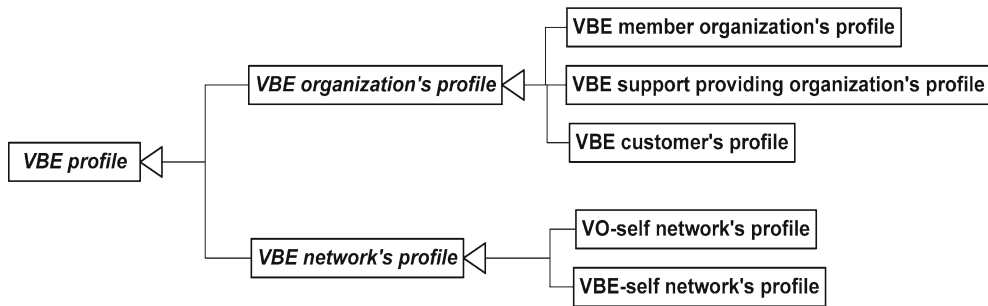
Fig. 1 Hierarchy of VBE entities

Fig. 2 Generalization hierarchy of VBE profiles

it is necessary that all VBE entities are represented by their up-to-date profiles. This requirement is even more severe in the case of the medium- to large-size VBEs, where the VBE members have less of a chance to get to know all VBE entities. As such profiles shall contain the most important pieces of information about the VBE entities, that is necessary in relation to the VBE activities.

Nevertheless, similar to a *CV/résumé* that can describe human individuals, here also depending on the type of the VBE entity the structure and elements of its profile may vary. Furthermore, for each VBE member organization, depending on its distinct specificities as well as the kinds of roles that it can assume in the VBE, the content of its profile varies.

The Virtual Organizations formed in the VBE also need to be presented both inside the VBE and outside for public. The *profiles of the VOs* constitute the main sets of textual information describing the VOs. In order to promote the VBE towards potential applicant members as well as the customers, *profile of the VBE network itself* is also needed to be developed. The hierarchy of VBE profiles is illustrated in Fig. 2.

Profile modeling for VBEs refers to the identification of profile structure and the elements of the structure that organize the profile content.

Profile management for VBEs constitutes a set of data manipulation operations that provide the profile data retrieval, cataloging, viewing, and analysis of VBE profiles.

The main motivation for organizing, modeling, and management of profiles for the five types of VBE entities is identified are addressed below in Table 1.

Modeling and management of profiles in VBEs is an open research area. The *main research challenges for the VBE profile management* are listed below:

- *Developing a unified/generic model for VBE profiles.* Considering the very wide variety and spectrum of domains, e.g. manufacturing, tourism, environment research, health care, etc. and well as the heterogeneous applications in each domain, identification, and categorization of different profiles and their elements in a unified/generic structure is challenging. The generic model shall be comprehensive so that it can be instantiated for any domain/applications for which a VBE can be established.

- *Continuous updating of profile data.* In today's changing market, a number of the organization's characteristics, e.g. resources (human, machinery, etc.), position in the market, financial status, organization's aim/strategy, details of its products, associated partners etc., are not static and are subject to change at different times during the life time of the organization. Therefore, people that represent VBE organizations, as well as those representing the VO networks that are established in the VBEs, face the difficulty of continuously providing up-to-date data about their organizations/networks. Automating a large part of this task is possible, although challenging.

- *Handling the confidentiality of profile data.* While a part of the profile data of each organization is public knowledge, another part of it needs to be handled as proprietary, e.g. the financial data of the VBE member organizations. Nevertheless, adding the private, restricted, and public categories on top of the profile data is not sufficient. Rather, different levels of authorization shall be defined on elements of the VBE organization profiles. These levels shall be granted to requesters/actors in the VBE, depending on the *roles* to which they are assigned.

Table 1 The motivation for profile organizing/modeling/management in VBEs

VBE entity	Motivation for organizing, modeling and management of profiles
VBE member organization	1. *Creation of awareness inside the VBE.* In order to successfully cooperate in the VBE and further successfully collaborate in VOs, the VBE members need to know each other. In small-size VBEs, e.g. with less then 30 members, VBE members may typically have the chance to get to know each other directly. However, this becomes more difficult and even impossible in the medium-size and large-size VBEs (e.g. with 100–200 members). Thus organizing of VBE members' profiles, e.g. to represent the members' contact data, industry sector, vision, role in the VBE, etc., is a critical instrument supporting awareness of the VBE members about each other
	2. *Selection of partners for new VOs.* The profile of the VBE member organization is needed to be accessed by both the human individuals and the software tools assisting the VO broker/VO planner to configure the VOs to best-fit partners. Therefore the information about members' qualification, resources, etc. that can be offered to a new VO needs to be structured and represented in the uniform profile format
	3. *Evaluation of members by the VBE administration.* At the stage of evaluating the members' application and also during the VBE members' participation in the VBE, the VBE administration needs to evaluate the members' suitability for the VBE. The members' profiles are also needed for automated assessment of members' trustworthiness and performance supported by software tools
	4. *Introduction/advertising in the marker/society.* Another reason for collection and management of VBE member's profiles is to introduce/advertise outside the VBE to the market/society and make it a part of the VBE-self network's profile. Similarly, for a VO its partners (who are a subset of VBE members) need to be introduced within the VO-self network's profile. The summarized information about VBE members registered in the VBE can be used to promote the VBE towards new VBE customers and therefore against of new collaborative opportunities
VBE support providing organization	1. *Acceptance and promotion towards VBE members.* This profile is needed by the VBE member organizations to investigate the qualifications of the support providers and to be able to compare them with each other. It is also needed by the VBE-admin to accept their application to the VBE
VBE customer organization	1. *Evaluation and acceptance by VBE-admin and VO broker.* This profile is needed by the VBE-admin and VO broker (even VBE member organization) to evaluate the organization behind the emerged opportunity (e.g. the call for tender)
VO-self network	1. *Introduction to the VBE members.* The VO-self networks need to be introduced inside the VBE for potential VO broker/VO planners and other VBE members
	2. *Evaluation of the VBE performance.* The automatic processing of the information provided inside the VO profiles is needed to assists the evaluation of the VBE performance, i.e. VBE's success in the VO creation
	3. *Introduction/advertising in the market/society.* Similarly to the VBE member profiles, the VO-self network profiles need to be introduced outside the VBE to the market/society. The summarized information, including the number, type, size, and new products/services of the VOs configured inside the VBE supports to create the impact of the VBE in the market/society and to promote the VBE towards new investments
VBE-self network	1. *Promotion towards new members and customers.* The VBE-self network needs to be introduced to the market/society in order to attract: (1) new VBE organizations (including potential VBE member organizations as well as different support providing organizations, and professional VO planners and coordinators), and (2) new potential VBE customers that issue business opportunities in order to create more VOs and make positive impact in the market/society. Thus the VBE-self profile is an instrument supporting the VBE's expansion and recognition
	2. *Provision of up-to-date information about the VBE to the VBE members.* At the same time also the VBE members need to receive the up-to-date profile information about the VBE-self network, its activities, achievements, and evolution

The roles of actors in VBEs are dynamically assigned to them by the VBE administrator, as explained in Afsarmanesh and Camarinha-Matos (2005).

VBE competencies

The *VBE competencies* provide a structured description of a *specific part of the profile descriptions* of the VBE entities, totally aimed to be used directly/indirectly for VO creation. As such as further addressed below, VBE competencies primarily address the capabilities and capacities of the VBE entities. Competency is identified in the previous research in the collaborative networks area as an important instrument towards VO formation. Organizing and management of competencies of the VBE member organizations also supports the creation of new collective competencies for the VOs (i.e. the VO-self networks) resulted from clustering of its related VBE member organizations. The VO planner looks for the VBE member organizations' competencies to select the right partners for a new VO. Different from the VO-self network, the VBE-self network does not have its own competencies. Rather, the VBE-self network represents a summary of its VBE members' competencies and its VO-self network's competencies.

The concept of competency has been traditionally defined as the set of knowledge, skills, and attitudes required for performing a certain process under some specific constraints (Galeano et al., 2007), For the VBE context however we shell define the VBE competencies while focusing on the specificities of the VBEs. For example, in the VBE where the primary aim is to use competencies for dynamic VO creation, the competencies of a VBE member organization, as identified in previous research (Afsarmanesh et al., 2005), do not only represent its capabilities. Rather, it also refers to some dynamically changing properties called capacities of an organization (e.g. availability of its varied resources). In other words, the needed VBE competencies for a VBE member organization should also represent the capacity available to get involved in a VO. Therefore, the definition of organization's competency in VBEs shall also consider organization's capacities to have its resources available. Besides the competency of VBE member organizations, the competency of other VBE entities, i.e. the VO-self networks and the VBE-self networks is also important for VBEs. The hierarchy of VBE competencies directly/indirectly related to VO creation is illustrated in Fig. 3. Please notice that the competency of VBE customers and VBE support providing organizations is of no consequence to the VO creation aim of the VBEs are therefore while their profiles are needed to be managed in VBEs, they are not contributing to the VBE competencies.

Competency modeling for VBEs addresses the identification of the structure and different descriptors of organizations/networks that together constitute their competencies.

Competency management for VBEs constitute a set of operations for competency cataloging and viewing, creation (e.g. in case of a VO-self network's competency) and analysis.

Since competencies are a part of profiles, the motivation for profiles is also valid for competencies. Therefore we address below some additional motivations for competencies. The main additional motivations for organizing, modeling, and management of competencies for the three types of VBE entities are identified and addressed below in Table 2.

Modeling and management of competencies in VBEs are challenging. VBE competencies are a part of the VBE profiles, so the challenges mentioned before for the VBE profiles are also valid here. Further to those a few *other challenges* can be identified *for competency modeling* and management, as listed below:

- *Unification of different existing representations*. Traditionally, every cluster/VBE has introduced different structure, with different elements and formats to represent its competencies (also see section "Profile/competency management in existing VBEs"). There is also no uniformity in the literature related to competency and the style for presenting it. Clearly, specification of a unified/generic model for VBE competency is strongly needed at least for their processing by the software tools in VBEs, if not also to simplify their processing by human actors in the VBEs.
- *Naming of the competencies*. With the lack of standards for *naming* the competencies in different domains and applications, it is clearly challenging for VBE entities 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, and remains an open area.
- *Cataloging of the competency*. 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 area. In practice, every VBE (typically small clusters) has developed its own very small base competency classification that it uses manually to match VBE competencies against the criteria required in emerging opportunities, e.g. calls for tenders. Managing competencies in large networks (for more then 50 organizations) need to formalize and
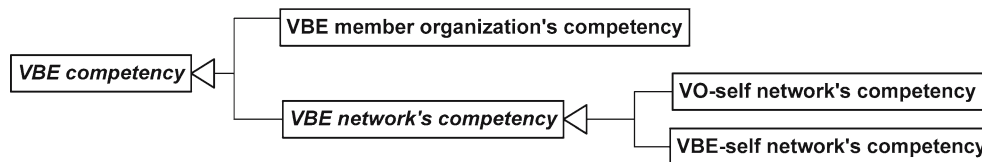
Fig. 3 Generalization hierarchy of VBE competencies

Table 2 The motivation for organizing/modeling/management of competency in VBEs

VBE entity	Motivation for organizing/modeling/management of competencies
VBE member organization	1. *Matching VBE members' competency details against the arose opportunity*. Details about a VBE member's competency such as availability of its resources, proof of qualification, etc. need to be provided for each competency. Therefore, there is a need for a detailed competency model for each VBE member organization
	2. *Determination of VO's competency*. For each VO, its competency needs to be defined as a combination of its partners' competency. Details about availability of partners' resources, proofs of activities that the VO partners offer to the VO, etc. are required. Therefore, the VBE members' competencies need to have a detailed model in order to determinate the VO-self networks' competency definitions
	3. *Processing the VBE members' competencies*. In medium- to large-size VBEs, processing (e.g. matching) of all member's competencies against deeded criteria of call for tenders is difficult and time-consuming, and thus needs to be performed by software tools. Therefore, a the unified format for competency definition is required
VO-self network	1. *Prediction of weak points in the VO-self network*. Besides the performance of the VO partner, the VO coordinator must also continuously observe the proper match between the detailed plan of activities in the VO versus the qualifications, availability of resources, etc. of VO partners, in order to identify the weak points and bottlenecks in the VO-self network and to prevent network failures. Therefore modeling of the detail VO-self network's competency is needed, as well as the links to the competency definitions of the VO partners (i.e. the VBE members)
VBE-self network	1. *Identifying competency gaps*. The summarized VBE-self network's competencies presented in the uniform format supports matching them against the VBE mission/expected competencies in order to find the gaps in the VBE-self network's competencies

semi-automate the classification of competencies in a uniform way, with the involvement of human experts.

Profile and competency management system

In order to apply the unified profile and competency models in practice, and to support the VBE with management of its profiles and competencies a system called *Profile and Competency Management System (PCMS)* is designed and specified in this paper.

The main research challenges identified and addressed for the design of the PCMS are listed below:

- *Adaptability of the PCMS to the wide varieties of VBE applications*. A wide variety of VBE application types may exist. In our study of the VBE applications, we have investigated a large number of characteristics on which the VBEs may differ, as follows: the VBE's *orientation* (e.g. business or social welfare), the VBE's (*business*) *area* (e.g. single sector VBEs or multi-sector VBEs), the

VBE's *level of dynamism* (e.g. dynamic pace or static pace of evolving), the VBE's *financial support* (e.g. publicly supported or privately supported), the VBE's *localization* (e.g. regional or non-regional), the VBE's *size* (e.g. under 20, above 1,000 members, etc.), the VBE's *mission* (e.g. profit-based or non-profit-based), the *ICT tools support* in the VBE (e.g. for base management services or for advance services), etc. as addressed in definition of the semi-typology for VBEs (Afsarmanesh & Camarinha-Matos, 2007). It is obvious that different types of VBE applications pose different requirements to the management of their profiles/competencies. The PCMS needs to be generalized enough and providing suitable mechanisms for adaptation to different VBE applications.

- *Sustainability of the PCMS in dynamic and expanding environments*. The dynamism of VBEs (including the continuous changes in VBE members and the VOs) requires that the PCMS is sustainable to support changes that are not pre-defined or predicted. For example, VBEs can expand their application environment and the (business) area/domain by inviting new VBE members with

additional competencies from different other "areas of activity", in order to satisfy some new market/society trends. On the other hand, for example during VBE's major evolution or metamorphosis, the size of the VBE can rapidly increase by registering a large number of new VBE members at once. This in turn means addition of a large number of new competencies at the VBE. Thus PCMS also needs to cope with such unpredicted changes. Developing some sustained mechanisms for this purpose is needed for the PCMS.

- *Replicability of the PCMS*. Creation of a profile and competency management system for each VBE is a challenge that causes a lot time and effort during the VBE creation stage. Human experts need to be assisted with this process and facilitating the instantiation and reliability of the PCMS for creation of each new VBE is certainly desirable.

This research is performed within the European ECO-LEAD project. The research and development work of this project primarily focuses in five different areas (as addressed in Fig. 4) such as the three "vertical areas" of the VO Breeding Environments (VBEs), Dynamic VO management and Professional Virtual Communities, and the two "horizontal areas" of the theoretical foundation for collaborative networks and the horizontal ICT infrastructure.

The results presented in this paper are related to the *VO Breeding Environment* (VBE) focus area. In relation to the VBEs, the main aims of the ECOLEAD include:

- understanding of the fundamental concepts, models, and mechanisms involved in the VBE, including its establishment's elements and features, and its operation principles;
- specification of VBE profiles and competencies, trust building support mechanisms, VBE value systems and metrics;
- design and prototyping of an ICT-based VBE management system providing generic tools and services for the instantiation and operation of the VBEs, as well as an ICT framework to support dynamic creation of VOs in the context of a VBE.

The main objective of this paper is to define a unified/generic model for VBE profiles/competencies, and to specify the PCMS for the VBEs. Section "State of the art on profiles and competencies of organizations and networks" of this paper addresses some state of the art research including first the study of existing systems for organizing organizations' profiles, second the research on organizations' competency models, third the study of profile/competency management approaches in existing VBEs, and fourth pro-
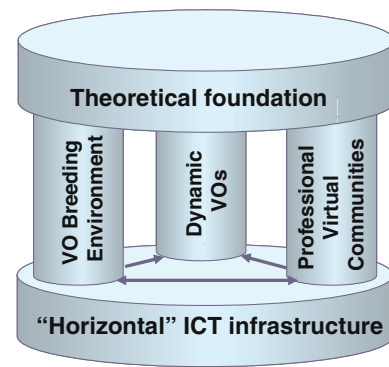

Fig. 4 ECOLEAD main components

viding the result of some empirical studies that address a list of to identify experts' requirements for the management of profiles and competencies in VBEs as identified by experts in the field. Section "Modeling VBE profiles and VBE competencies" addresses both the unified/generic model for profiles and the more specific unified/generic model for competencies in VBEs. Section "Profile and competency management system" describes the set of components constituting the PCMS, including the database for the profiles, the ontology, the services, and the approaches and mechanism for *semi-automated* derivation/discovery of elements for organization's profile and competency from on-line text corpora. Section "Conclusions" concludes the paper and addresses the next steps.

State of the art on profiles and competencies of organizations and networks

This section introduces both a summary of some related state of art in research and practice, as well as the results of some case studies in the area of profile and competency modeling and management for VBEs. Profile/competency modeling and management for VBEs is a new area of research, so the related research in this section only comes from the work on profile/competency management for enterprises and companies. But to complement this at the requirement analysis stage of our work, we also performed some case studies involving both the representatives of several existing business-oriented networks/clusters, as well as several academic experts who are involved in research in the fields of VOs and VBEs. Therefore, our proposed unified/generic model for profiles/competencies, as well as the functionality and specification of the PCMS addressed in this paper, target these identified requirements.

Collections of organizations' profiles in practice

Two strong examples of the existing profile collections, one governmental-level (Dutch) and one European-level are

studied in order to define a primary collection of profiles of commercial/non-commercial organizations. These two systems, addressed below, specify and classify a variety of information about organizations.

The Dutch Chamber of Commerce [Dutch Chamber of Commerce] has a trade register consisting of a large number of companies' profiles. Each company/organization is presented with the following data: contact information, information on the roles and functions, organization's legal form, date of establishment, number of employees/the size of the company, actual activities, summary of figures, annual accounts, etc. This register provides a good comprehensive example of collecting organization's information for profiles in VBEs.

An example of a collection of profiles for non-commercial organizations is the *EU register of organizations that are involved in proposal submission* [Proposal submission forms]. The structure of information used for these organizations includes the following: 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 [NACE] *addressed below in more details*, annual turnover, annual balance sheet total, number of employees, owners, affiliation, etc.

NACE that is developed for Europe, together with the NAICS and SIC that are developed for the USA and Latina America, are the well-known governmental standards for classification of organizations business activities. The name "NACE" comes from its French extension "Nomenclature général des Activités économique dans les Communautés Européennes". The main characteristics of the NACE system are defined by the following information:

- *area of the use*—Europe,
- *levels of hierarchical classification*—4,
- *number of all elements*—698,
- *elements represented at the first level of classification*— (1) Agriculture, hunting and forestry; (2) Fishing; (3) Mining and quarrying; (4) Manufacturing; (5) Electricity, gas, and water supply; (6) Construction; (7) Wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods; (8) Hotels and restaurants; (9) Transport, storage, and communication; (10) Financial intermediation; (11) Real estate, renting and business activities; (12) Public administration and defense; compulsory social security; (13) Education; (14) Health and social work; (15) Other community, social, and personal service activities; (16) Activities of households; (17) Extra-territorial organizations and bodies.

NACE is frequently used in different applications, among which it is used for developing the profile system for organizations. Since competency, in general, is an ability to perform a business process or activity, the NACE's classification of

activities is also used as a guideline for classification of competencies.

The profile elements introduced by the two above mentioned cases of profile collections are further summarized and applied for the VBE member organizations' profile models (see section "A unified/generic model for VBE profiles"). The NACE classification in its turn provides an example of competency classification/cataloging in the VBE.

Related research on organization's competency models

Different authors have proposed different definitions in the literature for competencies of organizations, mostly addressing competencies of commercial companies, with a few commonalities (Galeano, Ermilova, Giraldo, Afsarmanesh, & Molina, 2007). Below we address a few of the main definitions which contributed to our definition and model of competency for VBEs (also see section "A unified/generic model of VBE competencies").

Competencies are the capacity for a team of resources and capabilities to perform some task or activity. Competencies are the combination of *capabilities and resources* (Franke, 2002).

Competencies represent the capacity of existing resources plus the available capabilities/skills to perform some task or activity, applying those resources. Competencies are thus the combination of *capabilities and resource capacities* (Afsarmanesh & Camarinha-Matos, 2005).

Javidan (1998) defines the competency hierarchy as depicted in Fig. 5. 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.

Molina et al. (1997) defines competencies as the match between fulfilling the tasks defined by the VO broker with the constituent skills provided by the cluster. In their scenario there is a representation of competency which is describing the capability to make products, perform processes or use technologies (humans, practices, resources). Following this

Fig. 5 Competency hierarchy
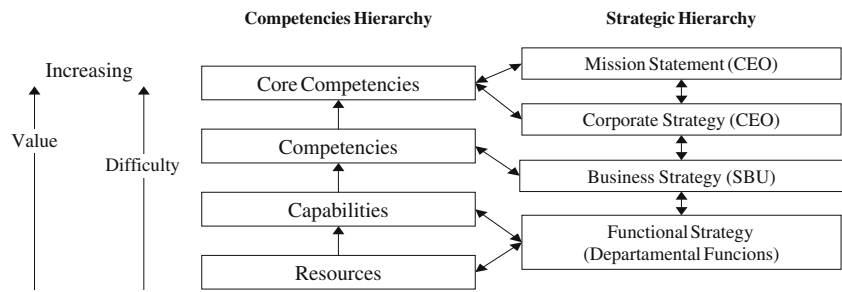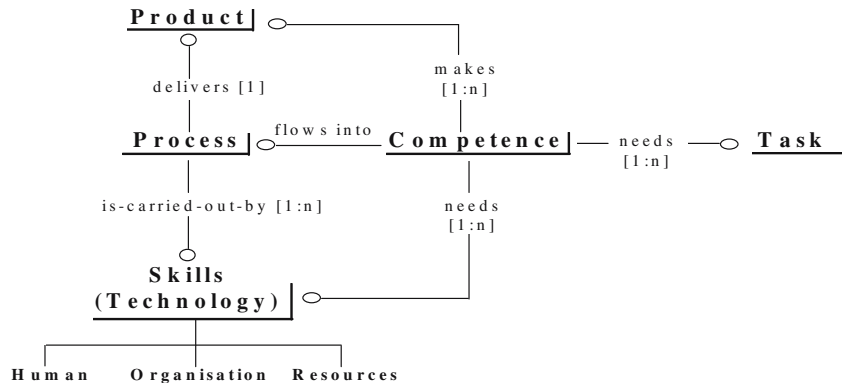and strategic hierarchy by
Javidan

Fig. 6 Representation of
competences by Molina et al

argument, competencies are described using the information
entities as illustrated in Fig. 6.

Products addressed in Fig. 6 can be the products of the
organization or the VBE, which are attractive from the per-
spective of the customer, and which make a substantial con-
tribution to organization's or VBE's success. Process in the
Fig. 6 refers to all the processes of the organization, e.g.
product development, order generation and fulfillment, inte-
grated logistics, etc. Skills (Technology) are theoretical and
practical knowledge, human skills, and abilities that can be
used to develop products and services. According to Molina
et al., a representation of competence, which satisfies this
definition, can be achieved by combining the information
entities of products, business processes and technologies.

The organization's descriptors (e.g. capability, capacity,
process, resource, product, etc.) addressed for competency
in the research works introduced in this section are further
summarized and applied to the design of the PCMS's unified
model for VBE entities' competency.

Profile/competency management in existing VBEs

The main aim to study and analyze the existing profile and
competency management approaches of running networks
of organizations was to design a more advanced and generic
PCMS, which can better fit diverse industrial domains and
specific VBE applications environments.

A questionnaire (here called Q1) is designed for collecting
information from running VBEs/clusters. This questionnaire
is one of the three questionnaires we prepared for our study that
together are illustrated in Fig. 7. Two other questionnaires

(i.e. Q2 and Q3) are addressed further in this paper in sec-
tion "Identified requirements of PCMS for emerging VBEs".
More details about these three questionnaires can be found
in Ermilova & Afsarmanesh (2006).

In this case study we purposely sampled VBEs from differ-
ent regions and countries for this study. Five VBEs from
Europe and Latina America were selected, including IECOS
(Mexico), Virtuelle Fabrik (Switzerland), Toolmaker Cluster
of Slovenia (Slovenia), GIZ ACS (Slovenia), and VIRFE-
BRAS (Brazil).

Analyzing the answers to Q1, following are some of the
main conclusions that have been drawn about managing the
VBEs' profiles and competencies.

- *The VBE profiles*. The main elements of the profiles for
  VBE member organizations, common among all investi-
  gated VBEs, consist of: the *general/contact information*,
  the information on *products/services, customers/suppli-
  ers, business processes, competencies, strategy and goals*
  of the company, and *ICT/human/physical resources*.
  Some of the VBEs are also concerned about the *financial
  data* related to the VBE members at the stage of their reg-
  istration. The main elements for the VO-self networks'
  profiles, as identified by the Q1 respondents, include:
  the *collaborative opportunity* information, the *type of the
  VO partnership*, and the *VO-self networks' business pro-
  cesses*. The main elements for the VBE-self network's
  profile, as identified by the Q1 respondents, include: the
  services that the VBE administration offers to the net-
  work, as well as the VBE administration's ICT related
  and business processes.

Fig. 7 Questionnaires Q1, Q2, and Q3 prepared for the case study and the PCMS requirement analysis

- *The VBE competencies*. The VBE case study revealed that at present the VBE members' competencies are in most cases represented by a combination of the member's products/services, business processes, and resources. The VO-self networks' competencies are represented by the new competencies resulted from the collaboration of the VO partners during the life time of the VO. The VBE-self network's competencies are represented by the collection of the VBE members' competencies.

- *Profile/competency management*. The case study also identified the main functionality currently applied in the VBEs related to the PCMS's profile/competency management. These include: (1) collection/update of data for profiles, (2) analysis of the VBE's performance, e.g. through observation of growth in the number of the VBE member organizations' competencies and the emergence of new collective VBE competencies, and (3) discovery of new emerging competencies for new VOs through the composition of existing competencies of potential VO partners.

Identified requirements of PCMS for emerging VBEs

Further to the study of the current practices, in order to identify the main requirements of the PCMS design, an empirical study was performed in collaboration with "experts" from both academia and industry. In this survey the experts were asked to specify the foreseen needed components and functionality for an advanced PCMS supporting the emerging VBEs. Two questionnaires (see also Fig. 7) were developed, one for the experts from academia (here called Q2), and a similar questionnaire for experts from industry (here called Q3).

In the study with academic experts more than 20 experts working in the area of VBEs/VOs were involved. Some main conclusions from the analysis of Q2 follow:

- *VBE profiles*. The common elements of the VBE profiles need to include *contact information, business process, human/physical/ICT resources, products/services, best practices*, and *associated partner organization* (mentioned as customer, supplier, as well as filial and corporation). The VBE member organization's profile needs to also show the *availability of member's competency* that is also called *free capacity* with a high level of detail. The VO-self network's profile need to include the *VO's type*, and the information about the *VO partners involved*. The VBE-self network's profile need to include the following elements: the VBE-self network's characteristics (e.g. a list of members, a list of services offered by the VBE administration to the VBE members, etc.) and some characteristics of the VBE members and its VOs. The VBE-self network's profile also needs to support the indication of what the VBE-self network can provide in order to promote itself towards new members and customers.

- *VBE competencies*. VBE competencies are associated with a variety of elements, such as an *ability to perform*

tasks, business processes, job, core business, activities, and practices applying human/physical/ICT resources (e.g. personnel knowledge, skills, attitude, as well as organization machinery) *aimed at offering products and/or services in the market*. Also the *availability of the VBE member organization's competency* offered to the potential VOs should be provided with a high level of detail.

- *PCMS's functionality*. The PCMS shall support profile creation, profile modification, analysis of VBE's evolution through the analysis of changes in profile catalogue, assessment of the VBE membership applicants according to their profile data, and analysis of VBE member organizations' competencies for creating a new VO. The features necessary for search of best-fit VO partners include: classification of organizations' profile information regarding different criteria (e.g. physical address/location, capabilities, etc.), including combination of several criteria. Collection, and if possible derivation, of the VBE member's profile information shall be performed either directly through structured questionnaires, or indirectly through text-mining of member's documents (e.g. websites, brochures).

The industry experts involved in responding to the Q3 questionnaire belonged to seven different organizations/companies involved in different running VBEs. Following are the main additional suggestions proposed by these contacted VBE member organizations, as the requirements to improve the PCMS's functionality in emerging VBEs. The responds from these experts further extended the above requirements, as these new elements are addressed below:

- *Additional profile elements*. The VBE member organizations' profiles need to have information about the VBE members' network of suppliers. This will help to find other companies recommended by the VBE members, e.g. to invite them into the VBE to both increase the competency of the VBE, and for them to also be invited to VOs.
- *Validity of profile data*. The issue of the profile information validity needs to be addressed in the VBE. The *customers' letters of recommendation* need to appear in the VBEs as well as the contact information about the person who signed this letter (information about the customer). Furthermore, a strict system shall exist to evaluate data provided by organizations, in order to assure data accuracy (e.g. not to claim false competencies by the VBE members).
- *Confidentiality of profile data*. The confidentiality of the profile information needs to be preserved. *The letters of confidentiality and non-disclosure* can be signed by VBE members to make sure that people who are going to use

the PCMS services will not use or disclose the information out of the necessary context.

Our proposed profile/competency models and the PCMS's functionalities suggested in this paper support and further extend the identified requirements in this section, as well as the required system functionality for the profile/competency management.

Modeling VBE profiles and VBE competencies

This section introduces unified/generic models for the VBE profiles and the VBE competencies. The section also presents some example profiles and competencies from the manufacturing VBE domain. A high-level abstraction of the main elements of unified/generic models of the VBE profiles and VBE competencies is illustrated in Fig. 8.

A unified/generic model for VBE profiles

A high-level generalization hierarchy of VBE profiles was introduced in Fig. 2. Below in Fig. 9, more details are provided for each class in that hierarchy. Namely their attributes are introduced. Please note that the attributes of each class in the generalization hierarchy are inherited by its sub-classes. As such, for example the profile of a VBE support providing organization includes its general data (i.e. the attribute inherited from the *VBE profile* class), also its contact data, financial data and evidence documents (i.e. the three attributes inherited from the *VBE organization's profile* class), as well as its product and resources (i.e. the two attributes specified for the *VBE support providing organization's profile* class).

In order to describe each of the attributes introduced in the generalization hierarchy of Fig. 9, we have introduced below one sub-section (e.g. P., P.1., P.2., etc.) for each class, where this numbering also reflects the location of the class in the generalization hierarchy. All attributes of each class are then briefly described in its related sub-section.

Please also notice that in the UML class diagrams illustrated in this paper, the symbol "+" next to an attribute means that the access to this attribute's data is allowed by public (e.g. has-generalData in class *VBE profile*), i.e. it can be accessed by all actors inside and outside the VBE. Similarly, the symbol "#" means that the attribute's data is restricted/protected (e.g. has-organization-financialData in class *VBE organization's profile*), i.e. it can be accessed only by certain authorized VBE members (including its owner) with the rights to access it (e.g. the VBE administration, or the VO broker, etc.). Furthermore, please notice that the pre-fix of "has" for an attribute indicates its reference to an object that defines its value, as opposed to having an atomic value.

Fig. 8 A high-level abstraction of the unified/generic models of the VBE profiles and VBE competencies
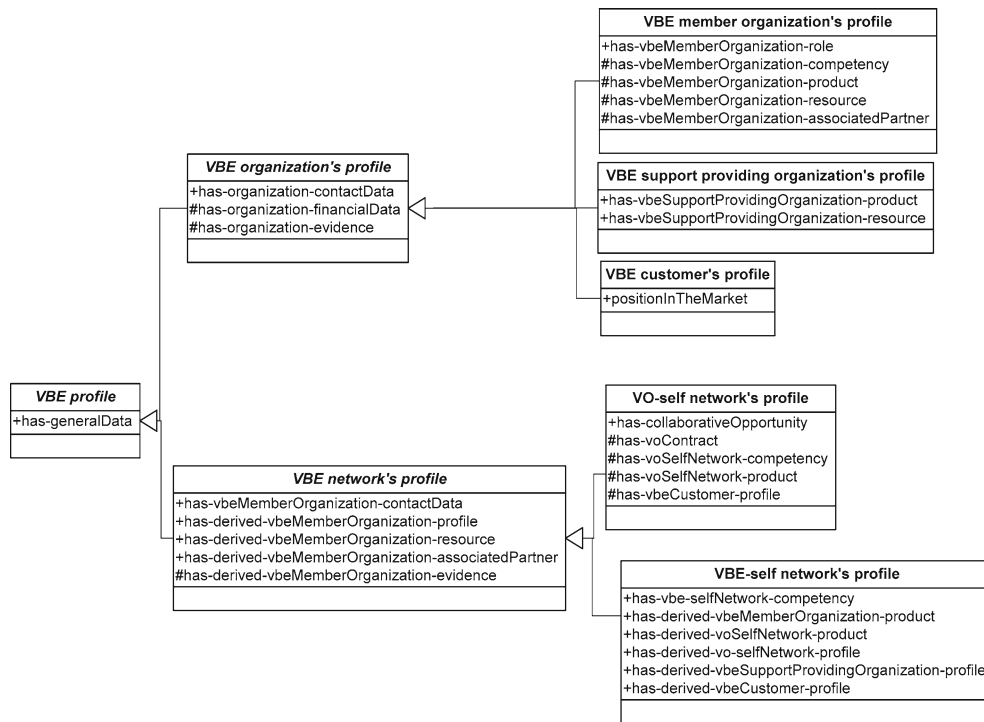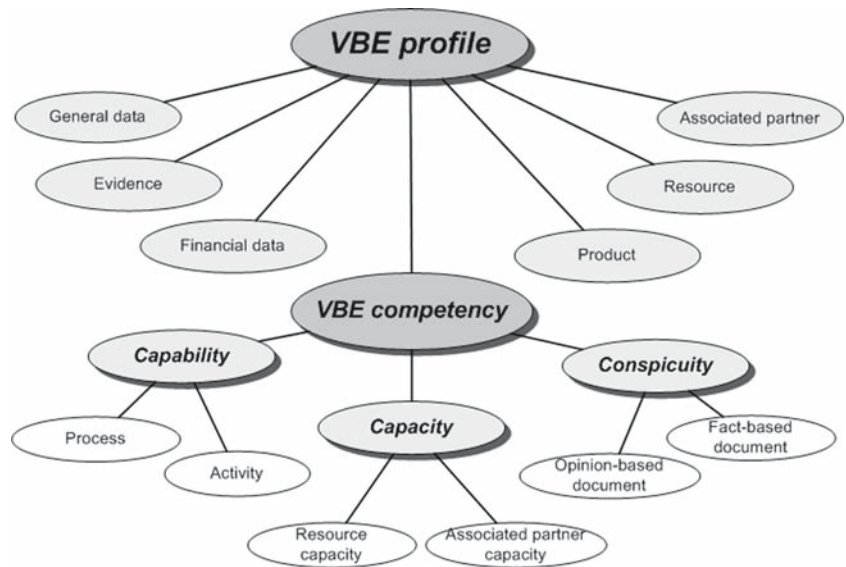
Fig. 9 Unified/generic model for VBE profiles

P. VBE profile elements

General data. This attribute represents the basic information about the VBE entity such as: the *name* of the organization/network, its *general description, legal status, date of creation, mission, vision, web-site, main activity, business area, size, strategy*, etc. Providing the general data is obligatory for all organizations/networks at the stage of their registration at the VBE. The general data is accessible by public.

Its main objective is to introduce the organization/network as a VBE entity, both inside the VBE and outside the VBE in the market/society.

P.1. VBE organizations' profile elements

Contact data. This attribute represents the information about: *legal address, phone/fax number* and the link to *the contact persons* (i.e. individuals within the organization). Similar to the general data, the contact data is also required to be pro-

vided at the stage of organization's registration in the VBE, and it is publicly accessible both inside and outside the VBE.

Financial data. Obtaining the organizations' financial information is typically required by the VBE in order to verify their financial stability. For instance, the financial stability of a VBE member organization is important in order to assure the VO broker that the organization will survive during the VO's operation, Similarly, the customer's financial stability is important, to make sure about its ability to survive and pay for the costs of the products/services of the VOs. The main descriptors include: *total sales, total revenue, annual balance*, and *operational costs*. Financial data collected from the organizations is 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).

Evidence. This attribute is introduced to represent the indication/proof of validity of the profile information provided by the organization. An evidence can either be an on-line document or some web accessible information, e.g. organization's brochures, web-site, etc. The evidence of information validity, can be of two different kinds including: the "*witnessed evidence*" documents (e.g. a letter of recommendation or an article in a magazine/news paper), and the "*authorized / certified evidence*" documents (e.g. accreditation statements, financial ratings, licenses, certificates, patents, and awards). Evidence documents can indicate the product quality, financial stability, etc., and they will be maintained in the VBE when provided by the organiztions.

P.1.1. VBE member organization's profile elements

Role. This attribute represents the current set of roles that the member organization plays in the VBE, e.g. VO coordinator, VO broker, etc. Roles are defined by their *name* and *duration*. The assignment of roles is done by the VBE administration once requested by the VBE member organization, and the data about roles can be accessed by all inside the VBE.

Competency. This attribute is later defined in section "A unified/generic model of VBE competencies". Access to the VBE member's competency may be restricted (e.g. the details about the competency of the VBE members (e.g. its current resource capacity, etc.) can be accessed only by the VO administration, and the authorized VO planner, or the VO coordination, etc.

Product. The product attribute represents the services and/ or goods developed by the VBE member organization in the past. The main descriptors of product include: *name, textual description, type* (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*.

Resource. The resource attribute represents the elements applied to business processes in the organizations. The following three types of resources are considered, including:

human resources, IT resources (e.g. software/hardware/communication facilities) and *physical resources* (e.g. buildings, equipment, machines, transport, and recorded information). The main descriptors of resources include: for human resource—*job function, educational level, professional field, degree obtained, years of experience*, and *number of employees*; for ICT resource—*description*, and *type* (e.g. software); and for physical resource—*description, type* (e.g. buildings), *number*, and *usage*.

Associated partner. An associated partner for a VBE member organization is a second organization (e.g. a sister company or a supplier) which has some (business) relations with the member. The main descriptors include: *name, relationship to the organization, and duration of collaboration*. The information about associated partners provided in the profiles also supports to further invite these organizations to the VBE as new members.

P.1.2 VBE support providing organization's profile elements

Product. The products of a VBE support providing organization are either the supporting services (e.g. insurance, training courses, consulting) and/or supporting tools (e.g. assisting software tools or ontology) that it offers to the VBE members. The descriptors include: *name, textual description, type* (i.e. of product or service),

Resource. The descriptors for resources of the VBE support providing organization include its: *human resources, facilities, and hardware/software tools.*

P.1.3 VBE customer's profile elements

Position in the market. The VBE customer needs to provide the information about its position/rating in the market. This information reassures that VBE administration and VO broker etc. of the stability of the customer in the market/society, and thus the viability of the opportunities announced in their call for tenders.

P.2. VBE networks' profile elements

Contact data. This attribute presents the contact data of the network's administrator/coordinator organization that is either the VBE-self network or one of the VO-self networks in the VBE. In either case, the organization in charge of administration/coordination of these networks is itself a VBE entity and has a VBE organization's profile.

Profile. This is a derived attribute that represents the list of profiles of all the constituting organizations (i.e. VBE members or VO partners) in the network. The list may represent some selected data of each VBE member/VO partner, e.g. *the name, main activity, web-site, etc.* The profile of the VBE

network is linked back to the profiles of its VBE member/partner organizations.

Resource. This is a derived attribute that represents the set of resources available at the network, through its constituting organizations (i.e. VBE members/VO partners). The recourses of a network are represented in its profile as a (derived) set of distinct resource names belonging to its members/partners. The resource of the VBE network is linked back to the resource descriptions of its VBE member/partner organization. Please note that while the VO-self network exploits the resources of its partners, the VBE-self network only represents the members' resources in its profile.

Associate partner. This is a derived attribute that represents the set of associated partners related to the constituting organizations (i.e. VBE members/VO partners) of the network.

Evidence. This is a derived attribute that represents the set of evidences available at the network, through its constituting organizations (i.e. VBE members/VO partners.

P.2.1. VO-self network's profile elements

Collaborative opportunity. This attribute represents the description and main characteristics and requirements of the opportunity emerged in the market/society for which the VO was configured to respond. Access to the detailed elements of the collaborative opportunity is restricted to actors inside of the VBE.

VO contract. The attribute represents the detailed information about the VO contracts. The main descriptors include the *type* of the VO contract (e.g. multiparty contract), the *involved parties* and other *details related to assignment of the partners' responsibilities* in the VO-self network.

Competency. This attribute is further addressed in section "A unified/generic model of VBE competencies". Access to the name and description the VO-self's competency is available to public.

Products. This attribute represents the services and/or goods being developed by the VO. The products of the VO are either provided to the customer who initiated the VO, or offered directly to the market when the VO is initiated by its partners within the VBE. While access to this product data is restricted to the customer in the first case, it may be made available to public in the latter case. The main descriptors of product include: *name, textual description, type* (i.e. of product or service), etc.

Profile—VO customer related. This attribute represents the profile of the customer who initiated the VO. The VO's customer isusually a VBE entity itself, in which case this profile links back to the VBE customer's profile as defined above.

P.2.2. VBE-self network's profile elements

Competency. This attribute is further addressed in section "A unified/generic model of VBE competencies". Access to the name and description the VO-self's competency is available to public.

Product—VBE member related. This is a derived attribute that represents the set of products (i.e. with no duplicates) developed by the VBE member organizations. These represent the products that may be of interest to certain potential VBE customer in relation to a call for tender. A distinct/unique set of *product names* will be derived here, where each product name for the VBE-self network is also linked back to the VBE member organization developing it. Access to these product names is available to all, inside and outside the VBE. Please note that VBE-self network does not produce any product, it rather represents these to the VBE customers as potential products that can be developed inside the VOs.

Product—VO network related. This is also a derived attribute that represents the set of products that can be developed by different VO networks in the VBE. These represent the products that may be of interest to certain potential VBE customer in relation to a call for tender. A distinct/unique set of *VO product names* will be derived, where each product name is also linked back to the VO network developing it. Please note that the VBE-self network does not produce any product, rather it represents these to the VBE customers as potential products that can be developed inside the VOs. Access to these product names is available to all, both inside and outside the VBE.

Profile—VO network related. This is a derived attribute representing the list of profiles of all the VO networks established inside the VBE. The list may represent some selected data of each VO, e.g. *the name, contact data, opportunity to which they responded, etc.* The profile of the VBE-self network here is linked back to the profiles of all its VO-self networks.

Profile—VBE support provider related. This is a derived attribute representing the list of profiles of all the VBE support providing organizations. The profile of the VBE-self network here is linked back to the profiles of all its involved support providing organizations. The list may represent some selected data about each of these organizations, e.g. *the name, service/tools that they provide, etc.*

Profile—VBE customer related. This is a derived attribute representing the list of profiles of the VBE customer organizations. The list may represent some selected data about each of these organizations, e.g. *the name, vision/mission descriptions, web-site, etc.* The profile of the VBE-self network here is also linked back to the profiles of its involved customer organizations.
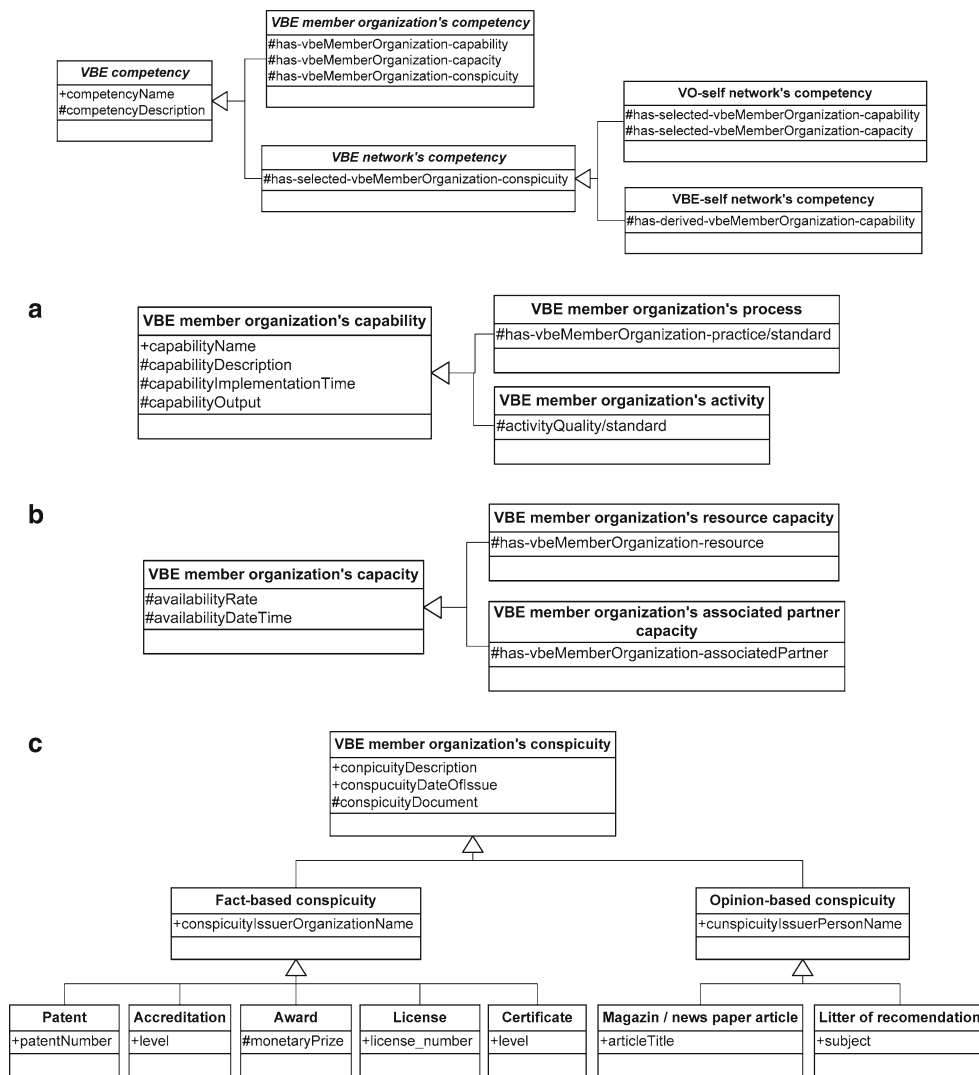
Fig. 10 Unified/generic model for VBE competencies (**a**) Capability of a VBE member organization. (**b**) Capacity of a VBE member organization. (**c**) Conspicuity for VBE member's competency

A unified/generic model of VBE competencies

A high-level generalization hierarchy for VBE competencies was introduced in Fig. 3. Below in Fig. 10, more details are provided for each class in that hierarchy, namely their attributes are introduced. Please note that the attributes of each class in the generalization hierarchy are inherited by its sub-classes. As such, for example the competency of a VBE-self network includes its name and description (i.e. attributes inherited from the *VBE competency* class), also its VBE members' conspicuity (i.e. the attribute inherited from the *VBE network's competency* class), as well as its VBE members' capability (i.e. the attribute specified for the *VBE-self network's competency* class).

Similarly to profile descriptions, in order to describe each of the attributes introduced in the generalization hierarchy of Fig. 10, we have introduced below one sub-section (e.g. C., C.1., C.2., etc.) for each class, where this numbering also reflects the location of the class in the generalization hierarchy. All attributes of each class are then briefly described in its related sub-section.

Definition of the *VBE member organization's competency*, as addressed in the previous research and also identified through questionnaires Q1 and Q2, can only be achieved through addressing several descriptors of the organization that together determine the competency. In an earlier definition of VBE member organization's competencies (Afsarmanesh & Camarinha-Matos, 2005), it is described that the mere specification of "capabilities" are not enough to represent the competencies of organizations. Rather, considering that dynamic VO creation is the main aim of the VBEs, organization competencies are reflected by the

"capability + capacity". The *capability* is described there as an ability "to perform some task or activity" and the *capacity* is described as the availability of resources. The need for a third competency descriptor called *conspicuity* was identified through our analysis of questionnaire Q3. In this context conspicuity refers to a set of *documents* (e.g. letter of recommendation, certification, etc.), that validate other competency data provided by the VBE member organizations. The main reason for introducing the conspicuity documents in the VBE is to avoid baseless claims of competencies by organizations. Therefore the issue of verification/validation of the competency data is also necessary to be addressed. Therefore the unified/generic model of competency constitutes the trio of "capability–capacity–conspicuity" that we refer to as "3Cs". Some further descriptions of the competency constituents can be found in Fig. 10a, b, and c below.

C. VBE competency elements

Competency name. This attribute represents a mnemonic label given to the VBE competency.

Competency description. This attribute represents the textual description of the competency.

C.1. VBE member organization's competency elements

Capability. This attribute represents the list of all abilities of the VBE member organization that can be applied within the emerging VOs. Since *capability* represents an important constituent of the competencies, below more details and descriptions are provided for this attribute.

Capabilities of a VBE member organization represent the set of *processes* and *activities* that on one hand this organization is able to perform and on the other hand they can potentially contribute to VO developments, and thus qualifying this organization for partnership in VOs. The main attributes for the Capability class include the *name, description, implementation time*, and *output*. Below more details are provided about the two sub-classes of capability, namely the Process and Activity.

A *process* (e.g. manufacturing processes) is defined in the literature as a structured and measured, managed and controlled set of interrelated and interacting actions that uses resources to transform inputs into specified outputs (Davenport, 1993) [ISO9004:2000, 2000]. Besides the attributes defined for the capability, the main further attribute for the process is the practice/standard applied to the process. *Practices* are used in order to improve the business processes in the organization (Stuhlman, 2006). A *practice* of an organization is typically defined as a standard technique, methodology, or procedure that is used in the organizations to perform a job.

An *activity* can be defined as a set of operations/actions that lead to accomplishment of some results, over a period of time, and with the possibility of repetition. Besides the attributes defined for capability, the main further attribute for the activity is the quality/standard applied to the activity. Consider the example of training activity. Typically educational institutes (e.g. Universities) apply higher quality to their training activities than private training companies. Therefore, the *quality*, applied to activities, is a counterpart to the practice, applied to processes, aiming to use standard techniques and methodologies in the organizations, to improve the quality of the performed job.

The UML diagram addressing the capability class is illustrated in Fig. 10a.

Capacity. This attribute represents the availabilities of resources in the VBE member organization that can be applied within the emerging VOs. Since *capacity* represents an important constituent of the competencies, below more details and descriptions are provided for this attribute.

Capacity of the VBE member organization translates into the current ability of the organization to participate in emerging VOs by referring to the availability *rate/percentage* and *date/time* of both the VBE member's *resources* and the VBE member's *associated partners.* The class definition for both resources and associated partners were provided in section *P*.2 earlier in this section. The UML diagram addressing the capacity class is illustrated in Fig. 10b.

Conspicuity. This attribute represents the set of documents that can indicate the validity of other competency data provided by the organizations. Since *conspicuity* represents an important constituent of the competencies, below more details and descriptions are provided for this attribute.

Conspicuity of the competency data provided by the VBE member organizations can be represented by a number of different documents that can add different level of validity to their claims. The two main sub-classes of conspicuity are identified in this paper as the *fact-based conspicuity* (e.g. certificates, awards, patents) and *opinion-based conspicuity* (e.g. letters of recommendation). The classification of the conspicuity documents is addressed below in Fig. 10c. The main attributes of the conspicuity class include: *description, date of issue, document* that refers to the scanned form of the physical document, and the *issuer's name*.

C.2. VBE network's competency elements

Conspicuity. This attribute represents the set of documents, all belonging to the VBE member organizations related to this VBE network. The VBE networks themselves do not own any conspicuity documents; rather all of their documents belong to their member/partner organizations. However, the validity of the collective competencies of a VBE network can still be checked through the conspicuity documents of its related VBE member organizations. The VBE network's competency is a collective competency, so the network's

administrator/coordinator decides on the set of needed conspicuity documents from its member organizations that it considers sufficient to validate its competencies. Therefore the VBE network's conspicuity documents are a *selected* set from the whole set of its member organizations' conspicuity documents.

C.2.1. VO-self network's competency elements

Capability. This attribute represents the set of capabilities (no duplicates) of its partner organizations that are applied inside the VO. In other words, not all the capabilities of the VO partners are used within the VO, and thus they cannot be represented as the capabilities of the VO-self network. Therefore, the VBE-self network's capabilities are represented only by a *selected* set of the capabilities from the whole set of capabilities of VO partners (i.e. the VBE member organizations related to the VO-self network).

Capacity. This attribute represents the set of capacities of its partner organizations that are applied inside the VO. In other words, similar to the VO-self network's capabilities, not all the capacities of the VO partners are used within the VO. Therefore, the VO-self network's capacities are represented only by a *selected* set of the capacities from the whole set of capacities of VO partners.

C.2.2. VBE-self network's competency elements

Capability. This attribute represents a set of all capabilities (no duplicates) of all its VBE member organizations and its VOs, that can be applied within the emerging VOs inside the VBEs. This in turn also means no duplicates in the set of names of the processes, activities, practices, etc. constituting the VBE-self network's competency. Therefore, the VBE-self network's capabilities are *derived* in the above manner out of the capabilities of its VBE member organizations.

Please note that the VBE-self network shows the *collective capabilities* of its members and VOs, to attract the customer and other potential organizations into getting involved with the VBE and increasing its chance of forming more VOs. At the same time it does not make sense to show any collective capacities, since capacities belong to individual VBE member organizations and VOs, and need to be negotiated as such for the VO formation. Thus, the VBE-self network's capacities do not need to be presented in the VBE-self network's competency model.

Examples of a VBE profile and a VBE competency

Tables 3 and 4 below represent an example of the profile and competency definition for a VBE member organization for the IECOS VBE [IECOS] in Mexico. When a new collaborative/business opportunity emerges through a call for tenders, a VBE broker can match this profile/competency description against the characterization and criteria specified in the call for tenders.

Please note that Table 4 below addresses the example for a VBE member organization's competency that is a part of the profile addressed in Table 3.

Profile and competency management system

This section addresses the design of the architecture for the *Profile and Competency Management System (PCMS)* for VBEs. The PCMS basically consists of the following four components (as also illustrated in Fig. 11):

1. the database for all profile and competency data;
2. the ontology for profiles and competencies;
3. a set of base services for managing the PCMS's information; and
4. an advanced mechanism for semi-automated derivation/discovery of data for profile elements applied specifically for competencies.

The four PCMS's components are addressed in more details further in this section.

PCMS's database

The information for the VBE profiles and VBE competencies needs to be maintained in a repository. An example of the relational database schema for the PCMS's competency data is illustrated in Fig. 12.

Figure 12 illustrates the example database schema for VBE competency's related data, e.g. capacities, capabilities, conspicuities, etc. The "entity" table in Fig. 12 represents the VBE entity's general data. The arrows in the Fig. 12 refer to the foreign keys "FK" in the database. Primary keys are also indicated as "PK" in the schema. Please note that this example does not provide the details for: (1) the VBE profiles classification, (2) VBE profile elements (e.g. resource) classification, (3) the derived/selected profile/competency elements (e.g. derived capacity of the VO-self network). The modeling of the full PCMS's database schema will be addressed in more details in the forthcoming papers.

PCMS's ontology

Ontologies are mainly used in artificial intelligence, the semantic web, software engineering and information architecture as a *form of knowledge representation about the world or some part of it*. These ontologies generally describe *classes* (i.e. main concepts or collections/types of objects), *attributes* (i.e. properties, features, characteristics, or parameters

Table 3 Example of a VBE member organization's profile

General data	
Name	Enterprise A1
Description	Machining services company with several years of experiences in automotive industry
Legal status	Anonymous Society of Variable Capital
Creation date	199X
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
Vision	Minor delivery times in comparison with the market. To comply in an objective and dedicated way with our commitments, conserving always a high quality in our job for entire satisfaction of our clients
Web-site	http://www.xxxxxxx.com.mx/
Primary activity	Metalworking
Contact data	
Legal address	Xxx Xxxxxxxxx 400, Monterrey, Mexico
Contact persons	Contact person 1:
	Xxxxxx Xxxxxx
	Project Manager
	Xxx Xxxxxxx 400, Monterrey, Mexico
	+52 (81) XXX-XX-XX
	xxxxxx@xxxxxxx.net.mx
	Contact person 2:
	. . .
Financial data	
Total sales last year	XX,000 USD
Total revenue last year	
Evidence	
Authorized/certified evidence	Certificate 1:
	Description: Quality Standard Certification ISO 9001:2000
	Date of issue: 2005
	License 1:
	. . .
Whiteness evidence	Letter of recommendation 1:
	. . .

Role

Role 1:

  Name: VBE member organization

  Duration: open-ended

Role 2:

 . . .

 Competency

Competency 1:

 (see Table 4 below)

Competency 2:

 . . .

Product

Product 1:

  Name: Machined products for thermal systems industry

  Description: . . .

  Type: goods

Table 3 continued

Product 2:	
. . .	
Resource	
Human resource	Human resource 1:
	Job function: Mechanical Engineers
	Number of employees: 1
	Description: Production planning and scheduling
	Human resource 2:
IT resource	IT resource 1:
	Name: MasterCAM
	Description: Offline programming of CNC machines
	Type: software
	IT resource 2:
	. . .
Physical resource	Physical resource 1:
	Name: MILLER Model 200
	Description: Welding Machine for a steel joining process
	Type: machinery
	Number: 2
	Physical resource 2:
	. . .
Associated partner	
Partner 1:	
Name: Enterprise B1	
Relationship: supplier	
Duration: since 2003	
Partner 2:	
. . .	

that objects can have and share), and *relations* (i.e. ways that objects can be related to one another). In general, the *reasons to construct ontologies* usually include: (a) sharing of the common understanding about the structure of information among people and software components, (b) enabling the reuse of the domain knowledge, separating the domain knowledge from the operational knowledge, and (c) analyzing the domain knowledge (Noy & McGuinness, 2001).

The definition of an ontology for the PCMS aims to achieve the following:

1. providing the *common understanding of the PCMS-related concepts, e.g. "VBE profile", "VBE competency", "resource", "product", "capacity", etc.* (as addressed in section "Modeling VBE profiles and VBE competencies") to be shared among all VBE actors/stakeholders,
2. facilitating the *reusability of knowledge accumulated in the PCMS of one VBE with* other VBEs,

3. *formal classification* of the PCMS's knowledge (e.g. competency) in order to facilitate the knowledge processing at VBE by software,
4. supporting the *interoperability of knowledge* intra-VBE (to support varied forms of collaboration), and inter-VBEs (through sharing the unified models of PCMS information/knowledge), and
5. *enabling the development of the PCMS's services* (as addressed in sections "PCMS's services" and "PCMS's semi-automated mechanisms" of this paper).

The *PCMS ontology* briefly defined in this paper consists of the two following levels, that refer to the two levels of the reusability of the PCMS related concepts:

- The *core level* represents the main PCMS related concepts, which can be reused by all varieties of VBE application environments, industry for example the "VBE

Table 4 Example of a VBE member organization's competency

Name	
Metalworking with focus on Machining and Stamping of high quality manufacturing pieces	
Description	
Six years of experience in CAM implementation	
Capability	
Process	Process 1:
	Name: Turning
	Description: Mechanical reducing
	Implementation time: . . .
	Practice: Computer Assisted Manufacturing (CAM)
	Output: Turning
	Process 2:
	Name: Deep Drawing
	Description: Deformation
	Implementation time: . . .
	Practice: Computer Assisted Manufacturing (CAM)
	Output: Deep Drawing
	Process 3:
	. . .
Activity	Activity 1:
	. . .
	Activity 2:
	. . .
Capacity	
Resource capacity	Resource capacity 1:
	Resource: Mechanical Engineers
	Availability rate: 50%
	Availability date/time: 2007
	Resource capacity 2:
	. . .
Associated partner capacity	Associated partner capacity 1:
	Associated partner: Enterprise B1
	Availability rate: 100%
	Availability date/time: 2007
	Associated partner capacity 2:
	. . .
Conspicuity	
Fact-based conspicuity	Certificate 1:
	Description: Quality Standard Certification ISO 9001:2000
	Date of issue: 2005
	License 1:
	. . .
Opinion-based conspicuity	Letter of recommendation 1:
	. . .

Fig. 11 Architecture of the PCMS
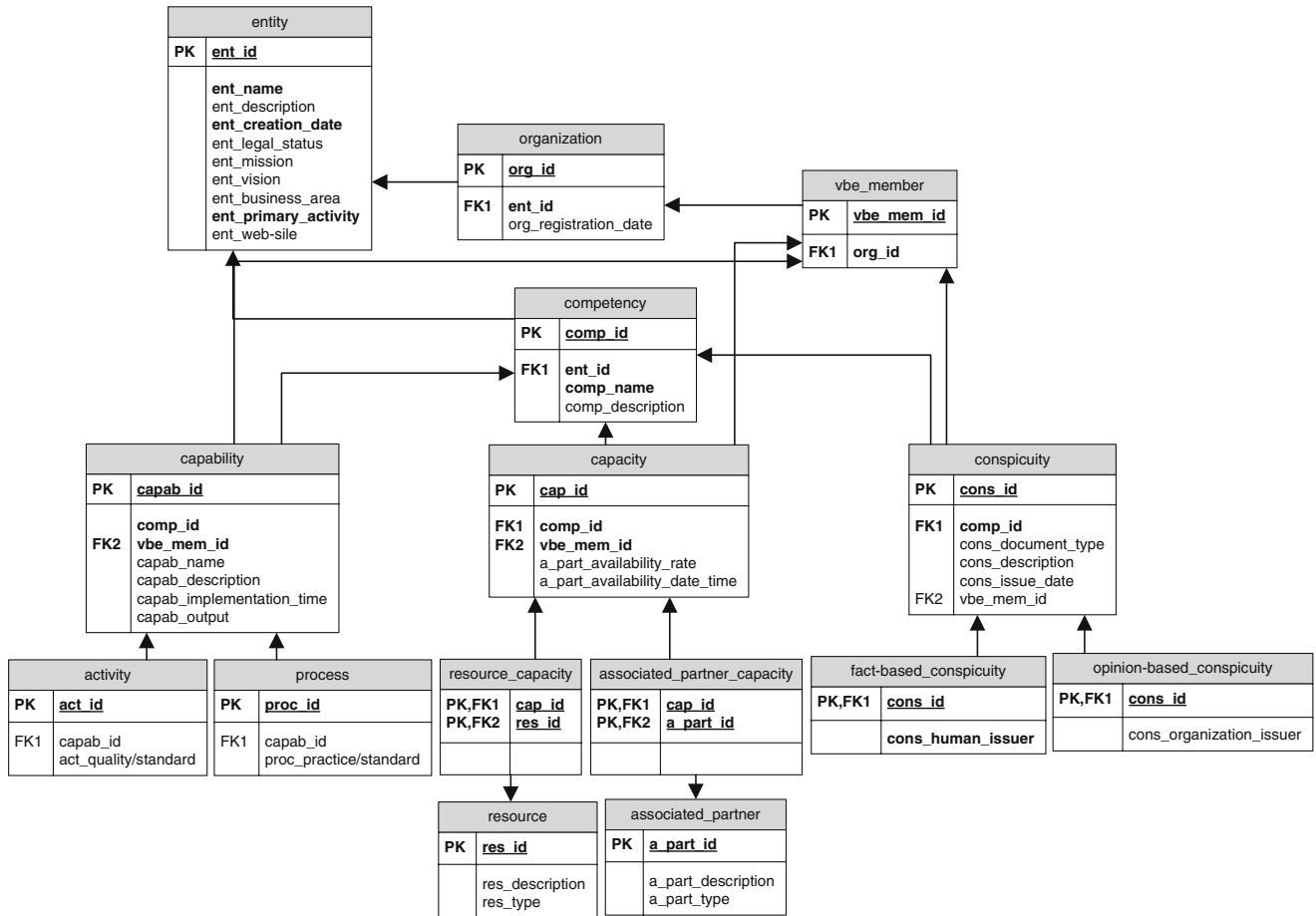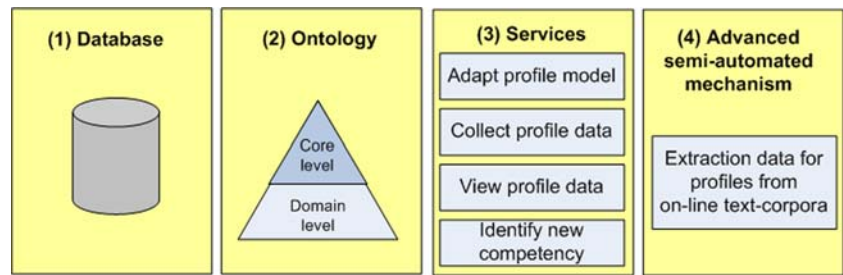
Fig. 12 The PCMS database schema for competency data

profile", "VBE competency", "resource", "general profile element", "evidence", "capability", "capacity" etc.), and

- the *domain level* representing the PCMS concepts related only to a specific VBE (business) area/domain (e.g. manufacturing, tourism, health care, etc.), where the VBE is operating, including specific competencies, such as "metalworking", and specific business processes such as "welding", "milling", etc.

The domain level can further include different classifications, e.g. domain competency classification, resource classification, etc. These classifications can for example be based on the NACE activity classification.

Please note that the core level of the PCMS is the small shaped ontology that can be pre-defined, we call it "manually constructed" while the domain level is large and differs for each VBE application environment. The approach for further semi-automated derivation/discovery of the domain level of the PCMS ontology is addressed in detail in section "PCMS's semi-automated mechanisms".

The main concepts of the PCMS ontology are summarized and addressed in Table 5 below:

The implementation of PCMS's ontology is constructed top-down and manually in Protégé-OWL editor. Figure 13 illustrates a screenshot from the common level of the PCMS ontology. The *left part* of the screenshot from Protégé

Table 5 Summary of the main concepts of the PCMS ontology

VBE profile	VBE competency
VBE profile subclasses and elements:	VBE competency subclasses and elements:
VBE profile	VBE competency
(General data)	(Name, Description)
• *VBE organization's profile* (Contact data, Financial data, Evidence)	• *VBE member organization's competency* (Capability, Capacity, Conspicuity)
• *VBE member organization's profile* (Role, Competency, Product, Resource, Associated Partner)	• *VBE network's competency* (Selected conspicuity of VBE members)
• *VBE support providing organization's profile* (Product, Resource)	• *VO-self network's competency* (Selected capability of VBE members and selected capacity of VBE mem-bers)
• *VBE customer organization's profile* (Position in the Marker)	• *VBE-self network's competency* (Derived capability of VBE mem-bers)
• *VBE network's profile*	VBE competency elements subclasses and descriptors:
(Admin./coordination org. profile data, Derived descriptions of VBE members, Derived VBE members' resource descriptions, Derived VBE members' assoc. partner descriptions, Derived VBE members' evidence descriptions)	*Capability* (Name, Description Implementation time, Output)
	• *Process* (Practice/standard)
	• *Activity* (Quality/standard)
• *VO-self network's profile* (Collaborative opportunity description, Contract description, Competency, Product, Customer)	*Capacity* (Availability Rate, Availability date/time)
	• *Resource capacity* (Resource)
• *VBE-self network's profile* (Competency, Derived VBE members' product descriptions, Derived VO-self networks' product descriptions, Derived description of VO-self networks, Derived descriptions of VBE support providing organizations, Derived descriptions of VBE customers)	• *Associated partner capacity* (Associated partner)
	Conspicuity (Document type, Description, date of issue)
	• *Opinion-based conspicuity* (Issuer person name)
	• *Fact-based conspicuity* (Issuer organization name)
	PCMS
	PCMS components:
	PCMS database
	PCMS service
	PCMS ontology
	PCMS advanced mechanisms

represents the classes in the ontology (e.g. "VBEmember Competency"), while the *right part* addresses the properties of the classes, including the class annotations (that refers to "comment") and relations (that refers to "hasCapability") the classes. Please note, that example of properties in illustrated in Fig. 13 for the "VBEmemberCompetency" class.

PCMS's services

A number of web-based services for management of VBE profiles and competencies are defined as the PCMS services. These services support the human individuals representing the VBE members (including the VBE administration and VO coordinator) with manipulation and management of the PCMS data.

The PCMS services are classified into four kinds. The first three kinds of services support the manipulation and management of the VBE profiles. The fourth kind of services addresses the management of VBE competencies.

1. *Services for adapting the unified/generic profile model to a specific VBE application.*
   This service supports adding/dropping some elements to/from the unified/generic profile model applied to the VBE database, in order to *adapt* it to a specific VBE application environment. For example VBE in health-care services, manufacturing, and disaster rescue missions need mostly different schemas for their VBE profiles. An advanced feature being designed and developed for this service supports the *automated tracing of PCMS ontology changes* (e.g. recording them in a special file), to be used for *gradually improving and adapting the generic profile model according to the latest version of the PCMS ontology.*

2. *Services for providing/collecting, and updating the profile data.*
   VBE members constitute a variety of sizes of organizations. While larger organizations are typically able to afford the time/cost provide and update their profile

Fig. 13 A screenshot from the PCMS ontology
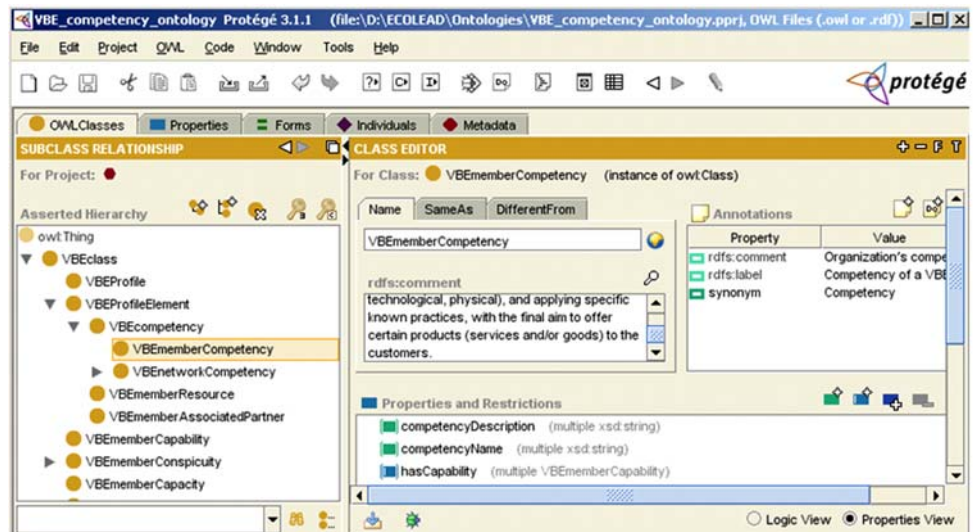
information, most SMEs (that may even have a handful of employees) lack the time and man power to provide this information, and/or to keep their profiles up-to-date. So it is a difficult task to obtain the date needed for members' profiles directly from the organizations. The number of VBE members can increase, typically rapidly during the VBE creation time, as well as gradually whenever new members join during the VBE operation stage. Therefore for time to time, the VBE members' profiles information needs to be processed (by the VBE administrator and other VBE experts e.g. ontology expert), in order to classify them, to extract the necessary general information about the VBE members, and to extend the competency catalogue for the VBE. This is a difficult and time consuming task.

The following set of services support to collect profile data mostly from VBE member organizations according to the PCMS's profile model. Three advanced features are designed as follows:

a. *Selecting elements by a human representative of a member organization O1 from the existing "data classifications" in the PCMS ontology, to best reflect the attributes and characteristics of the O1's profile.* This option assists the user (from a VBE member organization) to select the right "value" (e.g. by selecting/finding a specific organization's competency name) from the related "data classifications" (e.g. from the VBE (business) area/domain competency classification) that exist in the PCMS ontology (also see section "PCMS's ontology"). For example, if the current VBE's competency classification has N elements, then each organization can view these N elements, in order to choose the competency/competencies that best represent this organization, in order to be added to its profile.

b. *Semi-automated derivation/discovery of profile data through text-mining of online corpora.* This option allows obtaining VBE member organization's profile data semi-automatically, from the online documents provided by the member organization (e.g. web-sites, brochures, etc.). Section "PCMS's services" of this paper further addresses this service in more details.

c. *Automated tracing of the PCMS ontology changes.* This option supports *alarming the VBE member organizations if their profiles need to be updated*, due to the changes mode in the PCMS ontology.

3. *Service for viewing the profile data.*

Two important catalogues are necessary to be developed and managed by the PCMS, one *catalogue for the VBE members' profiles*, and another *catalogue for the VO's profiles.* The VBE members' profiles catalogue needs to provide as a collection of members' profiles, sorted by different types of VBE members' profile data. In this catalogue all the competencies, resources, product, etc., available in a VBE (through its members), shall be presented. Similarly, the catalogue of VO-self networks' profiles needs to be accessed as a collection of VOs' profiles, sorted by different types of VOs' profile data. A combination of these two catalogues into a single *VBE profiles catalogue* also needs to be developed to be accessed for viewing the general VBE profile data.

The service for viewing the profile data needs to allow retrieving certain required profile data from the PCMS database. The profile data can be further sorted, e.g. based on domain competency classification, and shall represent different "views". For example a view representing the profile of one organization, the VBE profile catalogue,

the VBE competency catalogue, or the VO resource catalogue, etc.

4. *Services for the identification of a new competency in the VBE.*

   The two services presented below are being developed for the PCMS primarily based on the search and comparison of the competency data available in the PCMS with the collaborative opportunity description.

   a. *Locating a needed competency in the VBE.* This service is usually initiated either by a VBE member (e.g. by a VO broker or the VBE administrator) or by another service that needs to find out if the general areas of activities in the VBE cover a "needed competency". For example, when checking the new call for tenders for collaboration opportunities, it is needed to find out if in general the call for tender is relevant to the VBE and therefore if it can support its needed competencies. This service compares the "*needed competencies*" against the *competency ontology* defined for the VBE, in order to locate and verify its existence.

   b. *Identifying the VBE members with specific competencies.* This service is usually initiated by a VO planner or another service that needs to identify the set of VBE members satisfying specific "needed competency". For example, for VO planning and configuration, it is necessary to first identify those VBE members that can offer the "needed competency" before choosing the best candidates for the VO. The service searches for the "needed competency" within the repository of competencies defined for all VBE members.

PCMS's semi-automated mechanisms

The mechanism suggested in this section for the PCMS applies and addresses the semi-automated processing of the following:

I. *Collect profile data from the VBE members* based on mining their related on-line text-corpora,

II. *Discover new ontology classes to extend the domain level of the PCMS ontology.*

This mechanism supports solving several of the challenges addressed earlier involved in developing an *adaptable, replicable, and sustainable* PCMS. It especially assists the representatives of the VBE members, the VOs, and the VBE (self) to identify the profile and competency information for the PCMS, and also to support the *evolution of the PCMS ontology.*

Our suggested semi-automated mechanism as applied to a specific VBE application is illustrated in Fig. 14. This mechanism allows to derive/discover the profile and competency data of a VBE member organization (e.g. the description of organization's processes) from its on-line text-documents (e.g. web-sites, brochures, etc.) using the PCMS ontology. Some of the new discovered elements for profiles will be then represented as the new classes in the domain level of the PCMS ontology.

Furthermore, we have performed some experiments applying our approach and prototype to the case of a running VBE in Mexico called IECOS [IECOS]. Our experiments have focused on the discovery of the domain ontology for IECOS, based on the semi-automated mining of the online text-corpora from its SME members. This experiment aimed to assist the human domain expert from the VBE of IECOS with the derivation/discovery of the members' competency data of IECOS, for potential extension of the PCMS ontology. Namely, the derivation stage of new competency elements is followed by the option for the expert to either extend the current PCMS ontology with the discovered element or to reject it. The domain area for this experiment is the Metal-mechanic and Plastic Industry (MPI) in Mexico.

In this section we address the steps of our proposed mechanism, as applied to the IECOS experiments. Following are the steps as also illustrated in Fig. 14.

- *Step 1: Preprocessing text-corpora.* The domain-related corpora of IECOS included web-pages (in English) from 23 SMEs that constituted the members of this virtual industrial cluster.
- *Step 2: Introducing lexical information in the ontology.* Several additional related pieces of information are necessary to be added to the PCMS ontology to facilitate the experiment, such as the definition of OWL meta-properties for the class definition, including the "Synonym" and the "Abbreviation", etc. The introduction of synonyms for example, helps to discover all variations of the same concept in the text-corpora.
- *Step 3: Preparing the thesaurus.* The thesaurus we developed for this purpose consists of a certain subset of the profile-related concepts of the PCMS's ontology. For the text-corpora, addressed in the IECOS experiment, the thesaurus included the concepts of *competency, process, resource*, and *practice*, as well as all their subclasses, synonyms and abbreviations, defined in the PCMS's ontology.
- *Step 4: Discovery of new ontology elements.* For each ontology concept/term in the thesaurus, the system discovers all its appearances in the text-corpora (i.e. the collection of processed web-pages). Using a special visual feature (e.g. the "facets" in tOKo), the discovered con-

Fig. 14 Semi-automated mechanism for discovery of organization's profile data and for evolution of the PCMS ontology
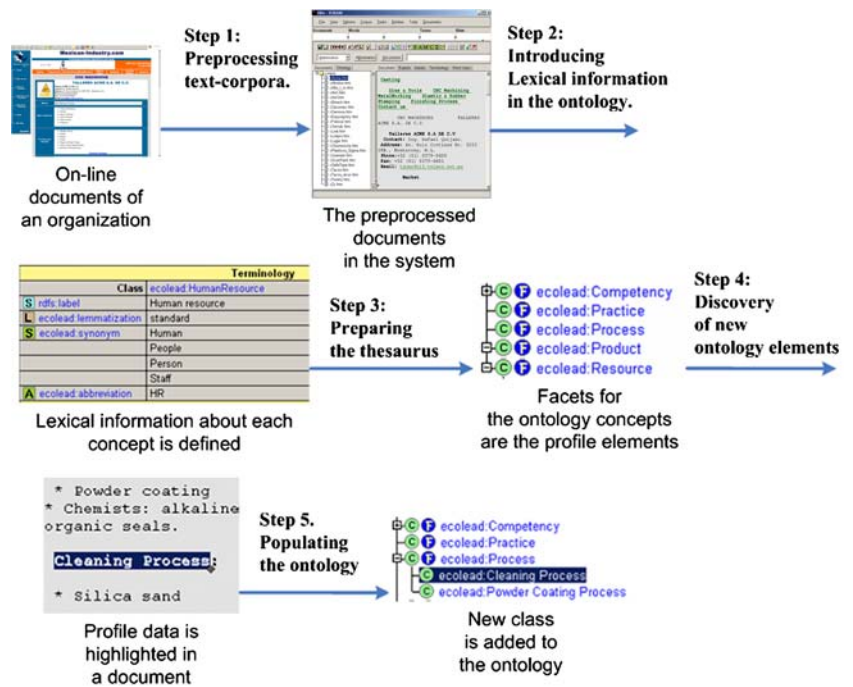
cepts/terms in the text-corpora can be marked with specific different colors, to make them visually distinguished. This assists the human domain experts with their analysis of the result.

- *Step 5. Populating the ontology*. The thesaurus-related concepts/terms will be located/identified in each document containing them, and presented to domain experts for consideration of extending the "domain level" of the PCMS ontology. Once the new discovered ontology element is agreed by the domain expert, it can be added to the current stage of the PCMS ontology as either a new class or a sub-class of an already existing class. Advanced user-friendly tools behaving similar to the "drag & drop" function, will be used for the creation of new ontology classes and locating them in the existing PCMS ontology. These tools are aimed at making the construction of a sustainable and extendable PCMS ontology easier and more user-friendly.

In the early implementation of our approach, we have used the tools called **tOKo** (for text-mining) and **Triple20** (for ontology editing) both resulted in the Metis research project (Anjewierden, Wielinga, Hoog, & Kabel, 2003). These tools will later be replaced by our own prototypes better fit the profile data discovery in VBEs.

Conclusions

Organizing/management of profiles and competencies are some of the key activities in the VBE. The paper motivates the need for definition of unified/generic models for VBE profiles and competencies. It addresses the main research challenges for this work.

Different kinds of **VBE profiles** need to be managed in the VBEs, consisting of the profiles for three heterogeneous types of VBE organizations, namely *the VBE member organization, the VBE support providing organization*, and *VBE customer organization*, and the two types of VBE networks, namely the *VO-self networks* and *the VBE-self networks*. The VBE profiles provide structured descriptions (of mostly textual content) about the VBE organizations and networks, addressing their qualifications, and the records of their related past activities and achievements. An important component of the VBE profile is its *competency*. Three kinds of *VBE competencies* need to be managed in VBEs, consisting of the *VBE member organization's competency, the VO-self competency, and the VBE-self competency*. This paper introduces the unified/generic models for VBE profiles and VBE competencies.

In order to maintain and manage the VBE profiles and competencies, the paper specifies the design of a system called PCMS—*Profile and Competency Management System*.

The contributions of the PCMS research are three-fold.

1st—specification of unified/generic models for the VBE profiles and VBE competencies that consist of: specification of the VBE entities and systematic definition of VBE profiles and for three kinds of VBE organizations and two kinds of VBE networks.

innovative modeling of the VBE competencies, introducing the "3Cs" model of capability, capacity, and conspicuity,

specification of the PCMS ontology addressing the VBE profiles and competencies, as a part of the VBE ontology 2nd—designing the PCMS with the aim of making it adaptable, sustainable, and replicable, to support its reuse in the wide variety of VBE domains and applications.

3rd—specification of a semi-automated (bottom-up) mechanism for derivation/discovery of profile and competency data from on-line text corpora.

In the next steps of this research the process of PCMS instantiation will be addressed, to enable the PCMS models for (semi-automatic) customization and adjusting to different applications. The instantiation process will be realized by a methodology with necessary steps to adapt the general information into specific information, and for creating the necessary catalogues of organizations' profiles and competencies, to be supported by the VBE Management System. Further modeling and prototyping the PCMS will also be addressed for forthcoming papers.

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