1

COMPETENCY MODELING TARGETED ON PROMOTION OF ORGANIZATIONS TOWARDS VO INVOLVEMENT

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During the last decades, a number of models is introduced in research, addressing different perspectives of the organizations' competencies in collaborative networks. This paper introduces the "4C-model", developed to address competencies of organizations, involved in Virtual organizations Breeding Environments (VBEs), from a new perspective. Design of the 4C-model aims at modeling those characteristics of organizations' competencies that are directly related to the criteria demanded in collaborative opportunities. As such, the 4C-model directly promotes these organizations for invitation / involvement in potential Virtual Organizations (VOs). The main components in the 4C-model include: Capabilities, Capacities, Costs, and Conspicuities, that constitute the 4C in this model. The paper further illustrates the applicability / validity of this approach to the context of VO creation. The introduced approach for competency-based creation of VOs in this paper also benefits from the introduction of other related concepts, namely "aggregate competency" and "collective competency".

1. INTRODUCTION

In earlier definitions, organization's competency is mainly addressing its capabilities, for example Gallon (Gallon et al, 1995) defines competency as "aggregation of capabilities, where synergy that is created has sustainable value and broad applicability". However participation of VBE members in general VBE activities such as the VO configuration, training, marketing, and trust establishment, require prior submission and analysis of their detailed competencies (Afsarmanesh & Camarinha-Matos, 2005). For example, in order to promote itself towards the invitation / involvement for new VOs, a VBE member must provide detailed and up-to-date information about its competencies. For this purpose, the information needed for an organization typically includes an accurate description of the member's capabilities, its free resources' capacities, the production costs for each of its product, as well as any conspicuous proof of the validity of the provided information. Based on the analysis of such competency information provided by all members, the VO broker selects the best-fit partners for a new VO.

In small VBEs (having less than 10 members), the competency information can perhaps be even transmitted orally from the VBE members to the VBE administrator and/or the VBE coach. However in medium and large VBEs depending on organization's complexity and especially in dynamic VBEs - continuously adjusting

their competencies to the changing conditions in the market/society - the collection and analysis of competency information by a human actor in the VBE is not anymore effective. In such VBEs, computer-based mechanisms for competency management are required.

Competency is generally considered as a "tacit knowledge", which is hard to comprehensively capture, model and represent. Furthermore, in different disciplines, competency is associated with different types of characteristics, e.g. from some intangible characteristics such as "knowledge" (HR-XML, 2001) and "attitude" (Andros Consultants, 2000) to tangible characteristics such as "resource" (Javidan, 1998) and "product" (Molina & Flores, 1999).

The competency model introduced in this paper and called the "4C-model" includes 4 main components, namely: capability, capability, cost, and conspicuity.

In this paper, we state and discuss that the definition, modeling and representation of organizations' competencies depend on the targeted objectives for this task and especially the target of promoting the VO creation in VBEs which is considered in this paper. In section 2, we address an overview of different competency models developed during the last decades, as well as their different objectives. Then in section 3, we introduce the objective of our research on competency modeling and management; namely the "promotion of the VBE member organizations towards their VO involvement". We also address some specific VBE requirements, related to competency modeling and management, for which our solution approach is presented in section 4. Further in section 5, we extend the 4C competency model and introduce new concepts of "aggregate competency" and "collective competency". Section 6 concludes this paper.

2. STATE OF THE ART IN ORGANIZATION COMPETENCY

This section subsequently presents several existing definitions and models for organization's competency, as being addressed in three disciplines of (1) intra-organization managerial sciences and industrial engineering, (2) inter-organization managerial sciences, and (3) networks managerial sciences. These disciplines although are related to each other, have different position in regards to the competency model, and thus the models defined in these disciplines also differ. The main objective for this section is to provide a comprehensive overview of different developed competency models in order to further position our 4C-model of competency, described in section 4, among the related research on competency models.

While the detailed description of all addressed state-of-the-art competency models is outside the scope of this paper, below Table 1 represents a survey of the main referenced models, specifically addressing their main objectives, competency definitions, and fundamental competency components. The main conclusion made out of the study is the following: Although the competency models are not uniform, they correspond to and inter-relate with each other via similar components. Depending on the context, where the competency is modeled, and depending on the purpose for modeling, similar components are extended with some more specific components.

Table 1 – State of the art works on organization's competency modeling

Ref.	Name of the model	Objective for competency modeling	Competency definition and/or fundamental components in the competency model
(1) Intra-organization managerial sciences			
(Prahalad & Hamel, 1990)	Core competence notion	Strategic planning and providing means for achieving better synergies among its various business units in a multi-business corporation.	"the collective learning in the organization, especially how to co-ordinate diverse production skills and integrate multiple streams of technologies" – Production skills – Technologies
(Javidan, 1998)	Core competence hierarchy	Extension of the core competency notion.	– Resources (physical resources, human resource, organizational resources Capabilities (organization abilities to exploit resources) – Competencies (cross-functional integration and coordination of capabilities) – Core competencies (skills and areas of knowledge that are shared across business units and result from integration and harmonization of SBUs' competencies)
(2) Inter-organization managerial sciences			
(HR-XML, 2001)	HR-XML competencies schema	Providing trading partners standardized and practical means to exchange information about competencies within a variety of business contexts	"a specific, identifiable, definable, and measurable knowledge, skill, ability and/or other deployment-related characteristic (e.g. attitude, behavior, physical ability) which a human resource may possess and which is necessary for, or material to, the performance of an activity within a specific business context" – Taxonomy Id – Competency Id – Competency Evidence – Competency Weight – Competency (resulted from the decomposition the "top-level" competency)
(3) Networks managerial sciences			
(Molina & Flores, 1999)	Core Competencies in the manufacturing clusters	Matching of fulfilling the tasks defined for a new VO against the constituent skills provided by the cluster of organizations	– Products – Processes (Business Processes) – Skills (Technology) – Task (set of activities/operations) service
(SFB457, 1999), (Mueller, 2006)	Competence cells	Planning of production system in the competence cell-based networks	"the smallest autonomous performance unit able to create value, be indivisible and able to exist independently" – Competence of humans – Resources (production areas, stocks, personnel, work equipment and auxiliary equipment, organizational and financial means) – Fulfilled task or executed function
(Boucher et al, 2005)	s-a-r-C model	Competence increase for individual firms within a network of firms	"the interaction between three components: the professional situations, the actors, and the resources" – Professional Situation (tasks and problems) – Actor (human resources of the firm) – Resource (material capabilities)

A summary of our main observations follow:

a. The competency definitions and models differ from one model to another, depending on the purpose for competency modeling.
b. There are two competency components that are common in all models, namely *(i) "resource"*, including "human resource" (also called "actor"), "physical resources", "ICT resources" (also called "technologies" or "skills") and a few other types of resources, and *(ii) "activity"* (also called "process", "production skill", "capability", "professional situation", "task" or "problem"). The absence of uniformity of naming of the same competency components is caused by difference in the context, where competency is being modeled.
c. Different models provide different extensions to the two-components-base addressed above in (b), such as the "taxonomy" and "classification" of competencies, as well as "competency weight" and "competency evidence" in (HR-XML, 2001).
d. The structure and level of details addressed in competency models depend on further intentions of using this specific model. Models, used for further creation of competency repositories, structuring and processing of competencies, such as in (HR-XML, 2001) are typically more detailed.

3. REQUIREMENTS FOR VBE COMPTETENCY

As specified in (Afsarmanesh & Camarinha-Matos, 2005), the main objective for competency definition, identified in the research on VBEs, is to support **competency-based configuration of VOs**, namely: (i) specific matching the VBE's competency collection against descriptions of the arisen Collaborative business Opportunities (COs) in the market / society and (ii) the selection of best-fit VO partners based on their competencies.

Our experimental study on the requirements for competencies in VBEs is performed in collaboration with several industrial VBE networks from Europe and Latin America, for example the SwissMicroTech (Switzerland), HELICE (Spain), CeBeNetwork (Germany), and IECOS (Mexico) within the IP-ECOLEAD project.

On the *first stage* of our study, we prepared and distributed a set of questionnaires, aimed to collect all requirements in relation to competency models and basic functionality for competency management. Responses from more than ten VBEs were gathered. The results generated from the analysis of this experimental study constitute the main criteria for our approach to modeling and management of organizations' competencies in VBEs. These criteria follow:
• In VBEs, organizations' competencies are required mainly for promotion of the VBE members towards involvement in potential VOs.
• Organizations' competencies are associated with a variety of elements in different VBEs, such as their ability to perform: tasks, business processes, job, core business activities and practices, and when applying a merge of human/physical/ICT resources (e.g. the knowledge, skills, and even attitude of the personnel, or the

machinery available at the organization), and furthermore aimed at offering different products and/or services in the market/society.

• Availability/capacity of the VBE member organization's competency, which can be offered to potential new VOs, should be provided with a high level of details.

• Validity of the provided competency information needs to be properly addressed in the VBE. For example, customers' letters of satisfaction/recommendation can be made available to VBEs, with the contact information of the person who signed this letter. Furthermore, a strict system (e.g. certificates) shall exist, with which VBEs can evaluate the data provided by organizations in order to assure information accuracy, so that organizations do not claim false competencies at the VBE level.

• New competencies may be generated in VOs.

• Competencies held by the VBE and that can be offered to the market/society are represented by the collection of the VBE members' competencies.

In the *second stage* of our study, we designed the 4C competency model and developed a software system to manage the organizations' competency related information. This system, called PCMS (Profile and Competency Management System) (Ermilova & Afsarmanesh, 2007), offers specific functionality and services for competency management based on the prepared competency model. These aim to process different aspects of the competency, introduced in the 4C-model, as well as to provide effective web-interfaces and web-services for both human and software access and processing of competency related information.

In the *third stage*, the 4C-model and the PCMS went through a series of trial evaluation and finally validation at running VBE networks associated with the ECOLEAD project. During this stage the competency model was improved and evolved. Another objective for the development of the VBE competency model was its proper alignment with the concepts introduced by previous research in this area as addressed in section 2. The final stage of the 4C competency model is presented in the next section.

4. 4C-MODEL OF COMPETENCY

The main objective of the "4C-model of competency" is the "promotion of the VBE member organizations towards their participation in future VOs". The four fundamental components of competency in this model represent: "Capability", "Capacity", "Cost" and "Conspicuity". A description, as well as a motivation for the appearance of each component in this model, is further addressed below. We provide the following definition of competency.

> *Organizations' competencies in VBEs represent up-to-date information about their capabilities, capacities, costs, as well as conspicuities, illustrating the accuracy of their provided information, all aimed at qualifying organizations for VBE participation, and mostly oriented towards their VO involvement.*

The main features that make the 4C-model unlike other models (as addressed in section 2) are the following:

- The 4C-model is developed in the context of VO creation within VBEs. Thus, the competency structure and main elements primarily intend to meet the specific VBE requirements (as addressed in section 3).
- The 4C-model is the base for development of a competency database, as well as the system for cataloguing and processing of competencies (i.e. the PCMS). Thus, the competency structure shall be detailed, and shall support further structuring and processing of the competencies.

4.1 Why 4 Cs?

Similar to other competency models addressed in section 2, the 4C competency model needed in VBEs has a compound structure. However, the primary emphasis in this model goes to the four following components, which are identified through our experimental study as necessary and sufficient components. The reasons why these elements are introduced as prerequisites for the 4C-model are addressed below:

1. **Capabilities** represent the capabilities of organizations, e.g. their processes and activities. When collective business processes are modeled for a new VO, the VO planner has to search for specific processes or activities that can be performed by single organizations, an order to instantiate the model.

2. **Capacities** represent free capacities of resources needed to perform one capability. Specific capacities of organizations are needed to fulfill the quantitative values of capabilities, e.g. amount of production units per day. If capacity of one member for a specific capability is not enough for a new VBE, another member (or a group of members) who has the same capability can be also invited.

3. **Costs** represent the costs of products/services provision in relation to one capability. They are needed to estimate if invitation of a specific group of members to a VO does not exceed the planned VO budget.

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

4.2 Generic 4C-model of competency

An illustration of the generic 4C-model of competency, applicable to all variety of VBEs, is addressed in Figure 1.

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┌─────────────────────────────────────────────────────────────┐
│ Competency                                                    │
│         ├── Competency-Class                                  │
│         ├── Competency-Description                            │
│         └── Capability                                        │
│                   ├── Capability-Class                        │
│                   ├── Capability-Description                  │
│                   └── Capacity                                │
│                             ├── Capacity-Measure              │
│                             ├── Capacity-Rate                 │
│                             ├── Resource                      │
│                             │         ├── Resource-Class      │
│                             │         ├── Resource-Description│
│                             │         └── Resource-Quantity   │
│                             └── Conspicuity                   │
│                   ├── Cost                                    │
│                   │     ├── Cost-Item                         │
│                   │     ├── Cost-Value                        │
│                   │     └── Conspicuity                       │
│                   └── Conspicuity                             │
│                             ├── Conspicuity-Class             │
│                             ├── Document-Title                │
│                             ├── Document-ID                   │
│                             ├── Issuer                        │
│                             └── Validity-Period               │
└─────────────────────────────────────────────────────────────┘
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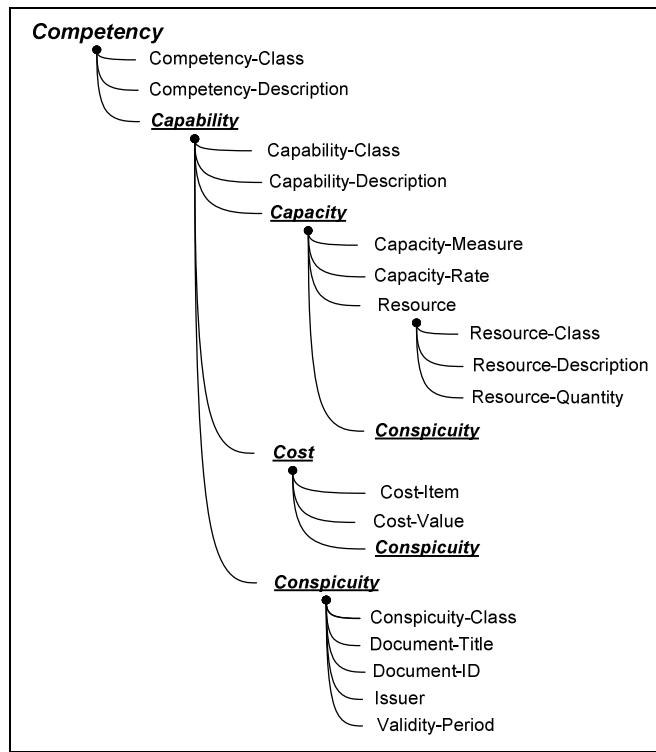
Figure 1 - Generic 4C-model of competency

Further, detailed definitions of all competency components are provided in Table 2. Please note that in the third column of this table we address if there is any correspondence/match between aspects introduced in the 4C-model of competency in comparison to other competency models, described in section 2.

Table 2 – Definitions of concepts represented in the 4C-model of competency

Concept:	Definition:	Match:
Competency	Competency is a compound object that cannot be represented by one textual value. The same as in (Javidan, 1998), in 4C-model, competency is associated with a set of specific capabilities.	(Javidan, 1998), (HR-XML, 2001)
Competency-Class	Competency can be classified by domains and their specific sectors, e.g. "metalworking competency", "health-care competency", etc. Competency can also belong to two or several classes.	
Competency-Description	Although a Competency-Class in general identifies a competency, a more extensive textual definition of each competency can be also provided.	
Capability	The capability is defined as an ability "to perform a task or activity". In our model Capability further refer to Capacity, which in fact represents Free Capacity of all Resources exploited within that Capability. Furthermore, we define two main types of capabilities, such as process (mainly for manufacturing domain) (Molina & Flores, 1999) and activity (for service-oriented domain).	(Javidan, 1998), (Molina & Flores, 1999)
Capability-	Capabilities can be classified. First, they can be divided into two	

Class	disjoint classes of "process" and "activity". Second, they can be further classified by the domain or a specific sector. Capability can also belong to two or several classes at the same time.	
Capability-Description	Although a Capability-Class in general identifies a capability, a more extensive textual definition of each capability can be also provided.	
Capacity	Capacity is described as the current availability of resources needed to perform one specific capability. The capacity component is mainly resulted from our study of VBE requirements.	-
Capacity-Measure	This represents a measure unit for a specific capacity, e.g. "thousands units per hour", or "hours a day".	
Capacity-Rate	This is a specific numeric value for capacity related to its measure unit, e.g. e.g. "20 thousands units per hour"	
Resource	The resource class represents the elements applied to business processes in the organizations.	
Resource-Class	Resources can be classified. First, they can be divided into four disjoint classes of "Human resources", "Physical resources", "ICT resources", and "Organizational resources" (e.g. brand and reputation). Further, for each class, the domain-specific sub-classes can be provided, such as "manufacturing machinery" for the "Physical resource" class.	(Molina & Flores, 1999)
Resource-Description	Although a Resource-Class in general identifies a resource, a more extensive textual definition of each specific resource can be also provided.	
Resource-Quantity	This is a number or amount of a specific resource, owned by a VBE member organization.	
Cost	Costs represent the costs of products/services provision in relation to one capability. They are needed to estimate if invitation of a specific group of members to a VO will not exceed the planned VO budget.	-
Cost-Item	This is an item, for that the cons is provided, for example "100 thousands units a day".	
Cost-Value	This is a monetary prize for a Cost-Item.	
Conspicuity	This knowledge class is introduced to represent the indication / proof of validity of the competency information provided by the organization. A conspicuity can either be an on-line document or some web accessible information, e.g. organization's brochures, web-site, etc. Conspicuity documents can indicate the product quality, financial stability, etc., and they will be maintained in the VBE when provided by the VBE entities. The main reason for introducing the conspicuity documents in the VBE is to avoid baseless claims of competencies by organizations. Therefore the issue of verification/validation of the competency data is also necessary to be addressed. The conspicuity component of competency mainly resulted from our study of VBE requirements.	(HR-XML, 2001)
Conspicuity-Class	The conspicuity of information validity, can be of two different kinds including: the "witnessed conspicuity" documents (e.g. a letter of recommendation or an article in a magazine/news section), and the "authorized / certified conspicuity" documents (e.g. accreditation statements, financial ratings, licenses, certificates, patents and awards).	
Document-Title	This is a title of a specific conspicuity document.	
Document-ID	This is a specific identifier (e.g. license number) of a conspicuity document.	
Issuer	This is the name of an organization, or a person, that issued a specific conspicuity document.	
Validity-Period	This is a validity period (e.g. March 2000 - March 2010) of a conspicuity document.	

4.3 Domain extension of the generic 4C-model of competency

Further to the elements of the generic 4C-model that are shared by all VBEs (as addressed in section 4.2) independent of their domain area application, there is a number of competency elements that are VBE domain (business area) dependent and/or specific VBE application dependent. To address the specifities of competencies in different VBE domains and application environments, while supporting the reusability and replicability of the model in different VBE domains/applications, the 4Cs-model of competency has three following levels:

▪ **Core level** that represents the generic competency model, applied to all VBEs (as addressed in section 4.2).

▪ **Domain level** that represents an extension of the core level with specific components related to each domain or business area of the VBEs. Many domain extensions can be defined for the competency model, depending on the number of different VBE activity/business domains existing in the market and society. All VBEs from the same domain can share the same domain extension. At the domain level, the domain extension is integrated to the object-classes (e.g. Competency-Class, Capability-Class) in the generic competency model of the core level (see Figure 1). For instance, as illustrated in Figure 2, the Capability-Class definition of the generic 4C-model at the core level is extended at the domain level with a number of domain specific capability classes (e.g. Metalworking, Product design, etc.). Please note that for the "Capacity" element in the 4C-model, the domain extension is applied to the Capacity-Measure element (see Figure 1).

▪ **Application level** that represents an extension of the domain level with new components related to every specific application environment of the VBE. Namely, each VBE has its own application extension. The application extension is also directly integrated to the domain extension of the generic competency model as the specific sub-classes of domain classes, e.g. for the capabilities, resources, etc.
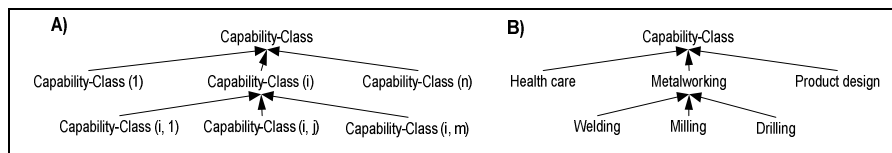

Figure 2 – Domain extension of the 4-C model of competency: A) generalized representation of domain capability extension and B) some exemplified domain capability extensions

Based on the domain and application classifications introduced in each VBE, the PCMS will organize/collect/group competencies and their components.

During the creation stage of every VBE's life cycle (Afsarmanesh & Camarinha-Matos, 2005), the domain and application level extensions for its competency model shall be created, while during the VBE's operation and evolution stage these extensions may further evolve.

Development of the domain/application extensions from scratch is a time-consuming task. However some "prototypes" of domain extensions exit and can be applied. For example, the activity classifications provided in the NACE codes

(NACE, 2008) represent a "prototype" for domain-dependent classifications of competencies and capabilities that can be used for VBEs.

5. AGGREGATE AND COLLECTIVE COMPETENCY

To properly support the competency-based VO creation in VBEs, this section introduces two new concepts of "aggregate competency" and "collective competency", as also illustrated in Figure 3.

An **aggregate competency** represents a *total* aggregation/merge of competency definitions of one, several, or of all members inside a VBE. This aggregation is primarily focused on (1) evaluation of the ability of a group of VBE members, or of all its members to address the criteria demanded through COs, (2) identification of the general competency gaps in the entire VBE while compared against most COs related to the VBE domain and application, as well as (3) preparation of VBE's aggregate competency catalog for the VBE customers as a part of VBE marketing activities.
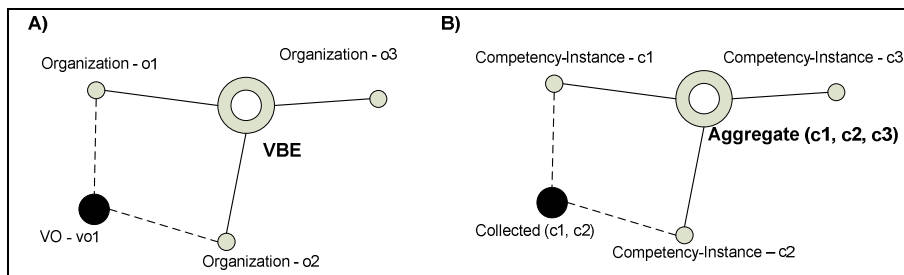

Figure 3 - A) Example VBE structure and B) Competency dissemination in the VBE

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

a. If two or more object-instances belong to the same class (e.g. Competency-Class, Capability-Class, as well as Capacity-Measure), they are merged into one aggregate object-instance. For example, if competencies c1, c2 and c3 (see Figure 3) belong to the same "Welding" class (see Figure 2), they become one aggregate competency-instance. If all of them belong to different classes, they remain separate instances. If two of them, e.g. c1 and c2, belong to the same Competency-Class, while c3 does not, the c1 and c2 instances become one aggregate competency instance, while the c3 instance remains a separate instance.

b. If the values for the same attribute of two or more aggregated object-instances (see a. above) are strings, they all become values of the same attribute of the aggregate object-instance. For example, if the competency-instances c1, c2, and c3 are aggregated in one instance, the Competency-Description attribute (see

Figure 1) of the resulted aggregate competency instance has 3 values that are equal to Competency-Descriptions of c1, c2, and c3.

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

d. If the values for the same attribute of two or more aggregated competency-instances (see a. above) are objects-instances (e.g. capability-instances), they are processed the same as competency-instances (i.e. from a. to e. above). For example, if the competency-instances c1, c2, and c3 are aggregated, the Capability attribute (see Figure 1) of the resulted aggregate competency is equal to the aggregation of all capabilities associated with c1, c2, and c3.

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

Definitions of all collective competencies shall be prepared manually matching VO Brokers' plans, based on COs, during the creation phase of each VO.

6. CONCLUSION

The main contribution of this research is the development of the "4C-model" for characterization of organizations' competencies. The model is specifically designed to addresses competencies of member organizations in Virtual organizations Breeding Environments (VBEs). It is targeted at the promotion of these organizations towards their invitation / involvement in potential Virtual Organizations (VOs).

This paper addresses several existing state-of-the-art competency models for organizations. It further positions the 4C-model of organization's competency among the other addressed models and illustrates its applicability/validity for the context of VO creation.

To better address the competency-based creation of VOs, the new concepts of "aggregate competency" and "collective competency" are introduced. The aggregate competency represents the aggregation/merging of all members' competencies within VBE. Aggregate competency is needed for performing activities such as identification of competency gaps in the entire VBE when considering the demands identified through the existing opportunities in the market/society. Similarly, VBE's aggregate competencies are required for the purpose of marketing of VBEs. The collective competency represents a partial merging of specific competency

components of VO partners, that fulfill the criteria specified in the VO's collaborative opportunity. As such, collective competencies of VO partners address and evaluate the ability of a group of VBE members to satisfy the VO requirements and thus to form a new VO. It is also required for calculation of remaining free capacities of each VBE member after its involvement in VOs. This paper also presents the approaches for derivation of aggregate competencies and collective competencies.

In the EC founded ECOLEAD project (ECOLEAD, 2008), based on the 4C-model of competencies, a database system is developed to manage the VBE members' competencies. Furthermore, a VBE competency management system is developed called PCMS to support the collection, cataloguing, and processing of different competencies in this environment. The description of this database and the management system of PCMS are the subject of a forthcoming paper.

Acknowledgements

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