01

ADVANCES IN COLLABORATIVE NETWORKED ORGANIZATIONS

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Collaborative networks represent a fundamental paradigm in modern industrial organizations. It is not only a survival factor or a mechanism to increase agility, but also a basis to promote innovation through collaboration. Aiming at giving a general overview of the area, this paper presents a summary of its current achievements and further research challenges.

1. INTRODUCTION

The information and communication technologies have been a fundamental "companion" of the manufacturing industry since the late 1970s. Along the last 3-4 decades many new approaches and paradigms were introduced, leading to progressive levels of integration, first inside the enterprise and lately in terms of networks of enterprises. The diagram of Fig. 1 briefly illustrates this evolution.

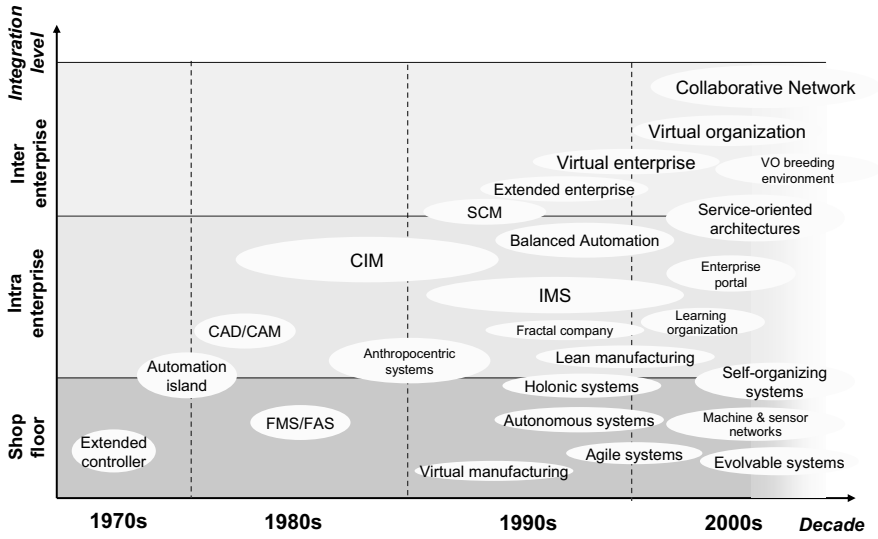

Figure 1. A brief historic evolution in manufacturing systems

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The diagram does not intend to give a precise "duration" for each paradigm, but rather an indication of the period when each topic was more "popular". As illustrated, although important challenges and activities are currently found at shop floor and intra-enterprise level, the inter-enterprise collaboration is becoming more and more important.

The need to consider the industrial developments in a more global perspective is also confirmed by prospective studies and recommendations such as the conclusions of the IMS Forum (IMS, 2006), shown in Fig. 2 (left side).

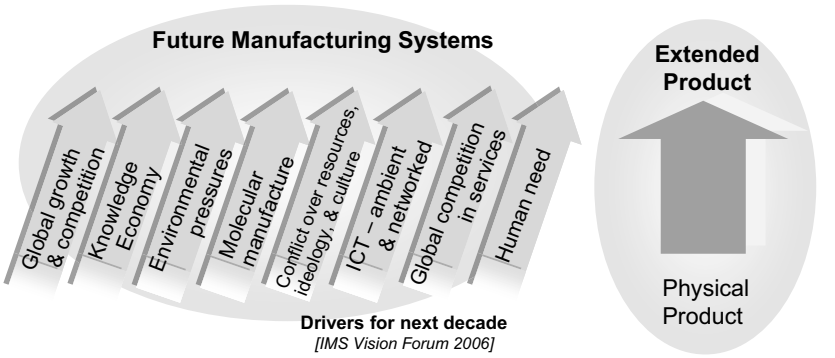


Figure 2. Manufacturing systems evolution drivers

The concept of product also evolved from the "physical product" to the notion of "extended product". This includes customized solutions to clients "embodying: intelligence as well as service capabilities in the form of real-time diagnostics, self-maintenance, security, traceability, self-direction, entertainment, convenience, responsiveness, and reciprocity" (Myers, 2006). The notions of social responsibility and sustainability also force companies to consider the full life cycle of the products / services, giving emphasis to life cycle management and end of life planning and operation. All these factors force companies to seek collaboration in order to better satisfy the market and societal demands.

2. COLLABORATIVE NETWORKS

In recent years the area of collaborative networks is being consolidated as a new discipline (Camarinha-Matos, Afsarmanesh, 2005) that encompasses and gives more structured support to a large diversity of collaboration forms. A collaborative network (CN) is a network consisting of a variety of entities (e.g. organizations, people, and even intelligent machines) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, and whose interactions are supported by computer network.

Most forms of collaborative networks, namely the cases found in industry, imply some kind of *organization* over the activities of their constituents, identifying roles for the participants, and some governance rules, and therefore, can be called manifestations of **collaborative networked organizations (CNOs)**. Other more spontaneous forms of collaboration in networks can also be foreseen. For instance, various **ad-hoc collaboration processes** can take place in virtual communities, namely those that are not business oriented – e.g. individual citizens contributions in case of a natural disaster, or

simple gathering of individuals for a social cause (Camarinha-Matos, Afsarmanesh, 2008). These are cases where people or organizations may volunteer to collaborate hoping to improve a general aim, with no pre-plan and/or structure on participants' roles and how their activities should proceed. Fig. 3 shows a partial taxonomy of collaborative networks.

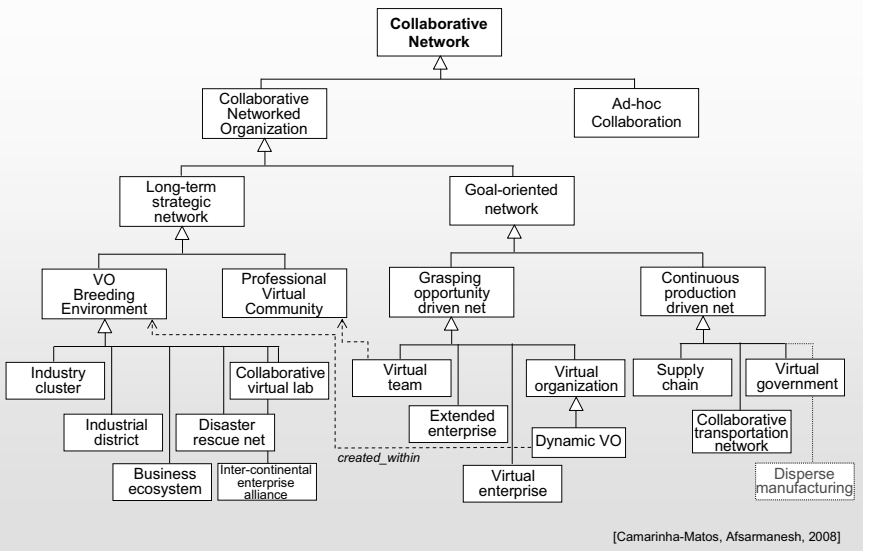


Figure 3. A partial taxonomy of collaborative networks

As shown in this taxonomy, among the CNOs it is important to distinguish between the long-term strategic networks or alliances and the goal-oriented networks. In fact many initial works on Virtual Organizations (VOs) / Virtual Enterprises (VEs) underestimated the difficulties of the creation process while advocating very dynamic scenarios. However, the agility and dynamism required for VOs are limited by the difficult process of establishing a common operational basis and building trust. The creation of long term associations of industry or service enterprises, an evolution of the industrial cluster concept, represents an approach to overcoming these obstacles and thus supporting the rapid formation of VO inspired by business opportunities. The concept of VO Breeding Environment (VBE) was introduced to represent this approach. A VBE represents an association of organizations and their related supporting institutions, adhering to a base long term cooperation agreement, and adoption of common operating principles and infrastructures, with the main goal of increasing their preparedness towards rapid configuration of temporary alliances for collaboration in potential Virtual Organizations. Namely, when a business opportunity is identified by one member (acting as a broker), a subset of VBE organizations can be selected to form a VE/VO (Afsarmanesh, Camarinha-Matos, 2005). A similar long-term organization is the Professional Virtual Community (PVC) which represents an alliance of professional individuals, providing an environment to facilitate the agile and fluid formation of Virtual Teams (VTs), similar to what VBE aims to provide for the VOs. A more comprehensive overview of the various classes of CNs can be found in (Camarinha-Matos, Afsarmanesh, 2008).

Many research initiatives and industrial developments have addressed different aspects of particular classes of CNOs during the last decades. However in most cases these initiatives corresponded to *fragmented* research and due to the funding and

assessment criteria, targeted very short-term objectives, focused on solving a specific problem. A more sustainable development of the area should be based on contributions of a multidisciplinary nature, namely from the information and communication technologies, socio-economic, operations research, organizational, business management, legal, social security, and ethical areas, among others. In this direction, the ECOLEAD project was launched in 2004 with the aim to create the necessary strong foundations and mechanisms for establishing an advanced collaborative and network-based industry society. ECOLEAD addressed three main focus areas: VO Breeding Environments (VBE), Virtual Organizations (VO), and Professional Virtual Communities (PVC), as well as their inter-relationships. These areas were complemented by research on horizontal ICT support infrastructures and contribution to a theoretical foundation for CNOs.

In parallel, several other international initiatives have been contributing to the development and consolidation of the new discipline. In the following sections a brief survey of the current state in the various areas is presented.

3. ICT INFRASTRUCTURES

The ICT infrastructure plays the role of a base enabler for effective, safe and coordinated interactions among the CNO members. In other words, it acts as a CNO "operating system" or executor, hiding the details of the collaborative network "machinery". Benefiting from the rapid development of the so-called Internet technologies, this has had a fast progress during last years.

Fig. 4 illustrates the current state of the art regarding general ICT support to CNOs. This diagram is not intended to give a full account of all developments in this extensive area but just to pinpoint the main building blocks and recent progress. Examples of relevant projects contributing to the area are also included.

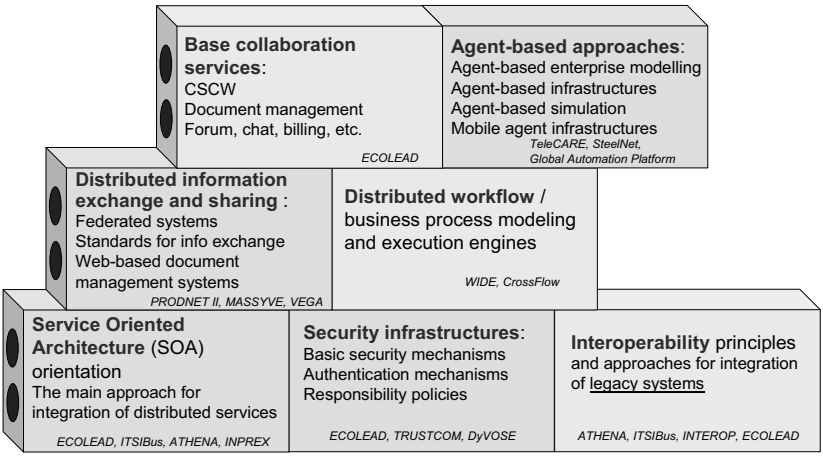


Figure 4. Progress in ICT infrastructures

While earlier efforts were focused on basic interoperability, secure communications, coordination and information sharing and exchange, current trends go towards advanced collaboration support services and semantic support.

Fig. 5 illustrates some of the challenges requiring further research in the area.

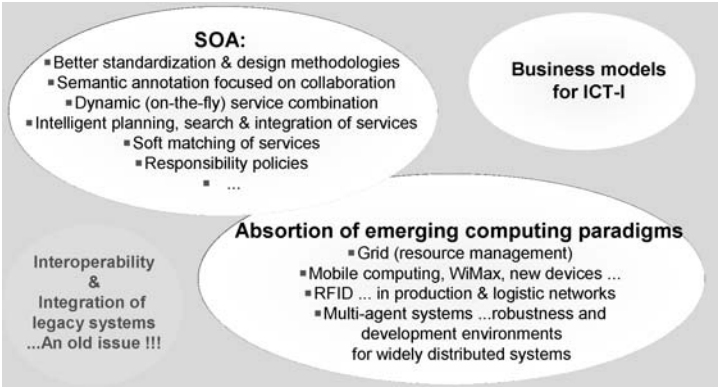


Figure 5. Some challenges in ICT infrastructures

4. VO BREEDING ENVIRONMENTS AND VO CREATION

Evolving from earlier concepts of industry cluster, industrial district or business ecosystem, the notion of Virtual organization Breeding Environment (VBE) was established as a more general concept encompassing these and other long-term strategic alliances. During last years substantial progress was achieved both in conceptual and methodological terms as well as development of support systems. Fig. 6 gives a brief summary of the main building blocks and corresponding elements developed in a number of recent projects, with particular relevance to ECOLEAD (Afsarmanesh, Camarinha-Matos, 2005).

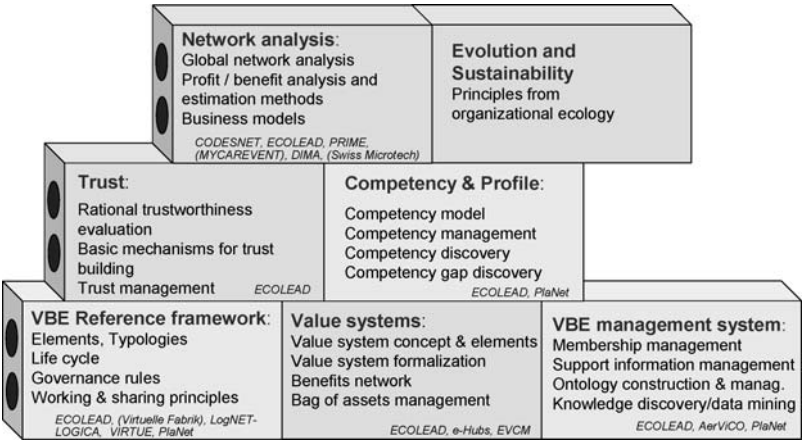


Figure 6. Progress in VO Breeding Environments

There are already a significant number of operational VBEs (Afsarmanesh, Camarinha-Matos, 2007). Nevertheless many challenges for further research have been identified, as illustrated in Fig. 7.

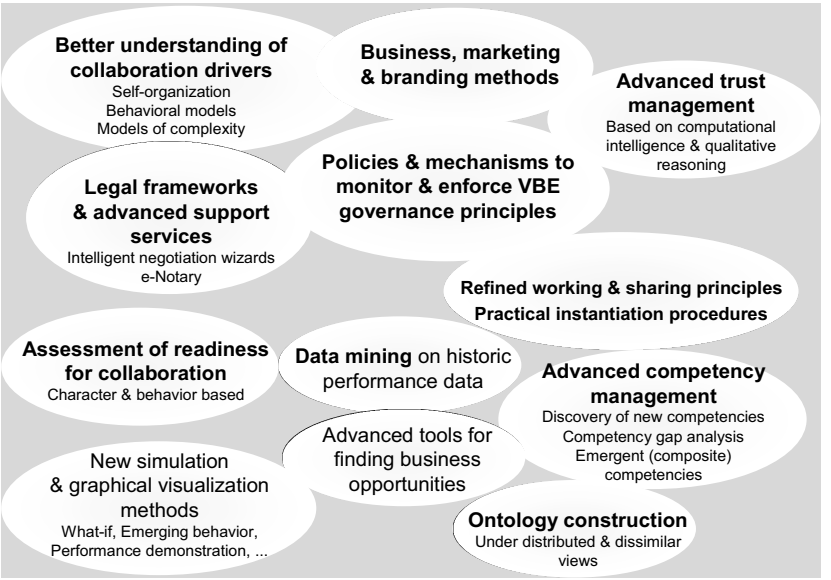


Figure 7. Further research challenges in VBEs

As the main purpose of these organizational structures is to make their members prepared to collaborate when a business opportunity is identified, a growing number of developments on VO creation are now conducted assuming a VBE as the underlying context. A summary of such recent developments is illustrated in Fig. 8.

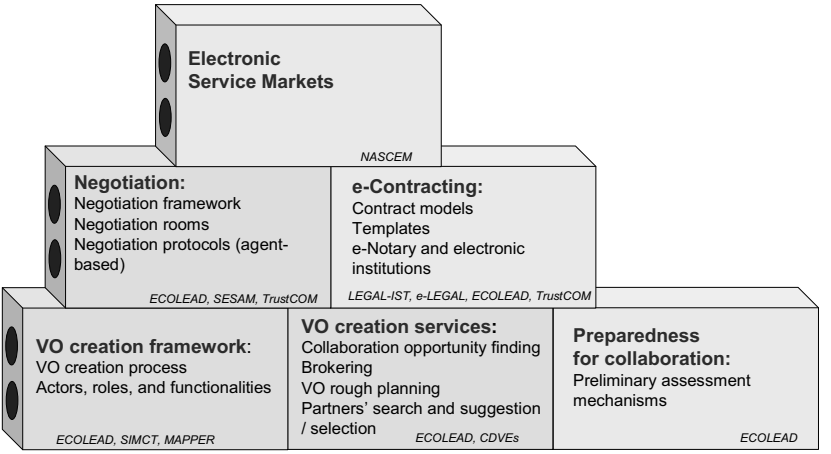


Figure 8. Progress in VO creation

It shall be mentioned that VO creation / consortia formation is one of the most addressed topics in research in the last 10 years. Nevertheless, many of the works on partner selection or negotiation, for instance, ignored the problems that are addressed by a VBE and therefore generated solutions with theoretical merit but somehow far from the actual needs in industry. More recently the efforts are becoming more focused on real business needs and new solutions, which are less automated and more in the line of decision-support tools, are being proposed.

5. VO MANAGEMENT

Substantial developments in the early days of VE/VO research were focused on supporting the operational phase of these networks, paying little attention to the other phases of the life cycle. However, being these organizations temporary, and often of a short duration, it is very important to devote attention to the creation, evolution and dissolution phases as well. More recent works have a more comprehensive scope and the area of VO management became an important research topic. Fig. 9 highlights recent developments in the topic, covering conceptual, methodological and technology developments aspects. Further research challenges are illustrated in Fig. 10.

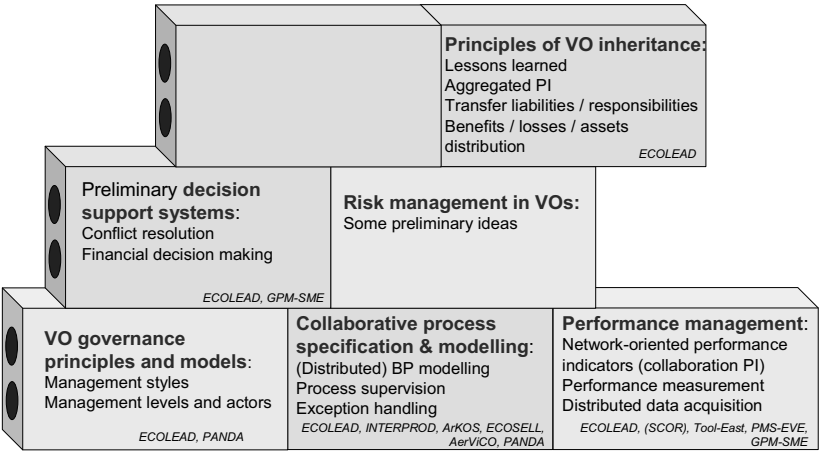


Figure 9. Progress in VO Management

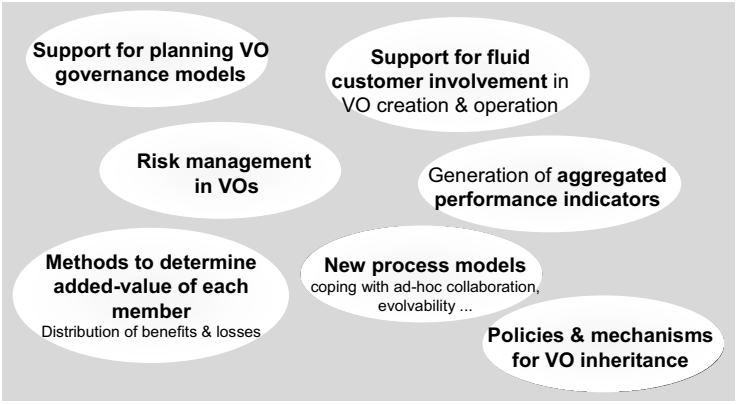


Figure 10. Some challenges in VO management

6. PROFESSIONAL VIRTUAL COMMUNITIES

The Professional Virtual Communities topic has its roots in different areas – virtual communities, communities of practice, and concurrent engineering - and thus represents an attempt to synthesize a new organizational structure based on synergies from those related areas. On the other hand, a PVC is another kind of "breeding environment" to facilitate the dynamic creation of virtual teams and thus gets inspiration on the previous developments in the area of VBEs.

As illustrated in Fig. 11, the main contributions of ECOLEAD in this area were on the conceptual and methodological side. Other projects have developed some tools and approaches for collaborative problem solving, namely in the AI and Collaborative Engineering communities, but an integrated framework and platform are still missing.

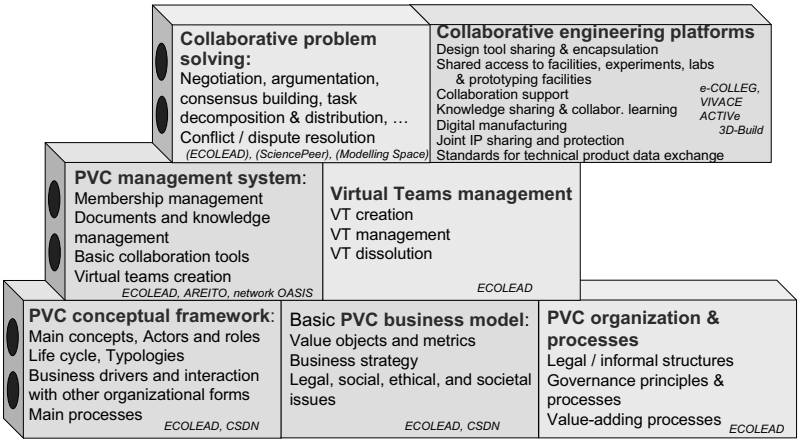


Figure 11. Progress in PVC

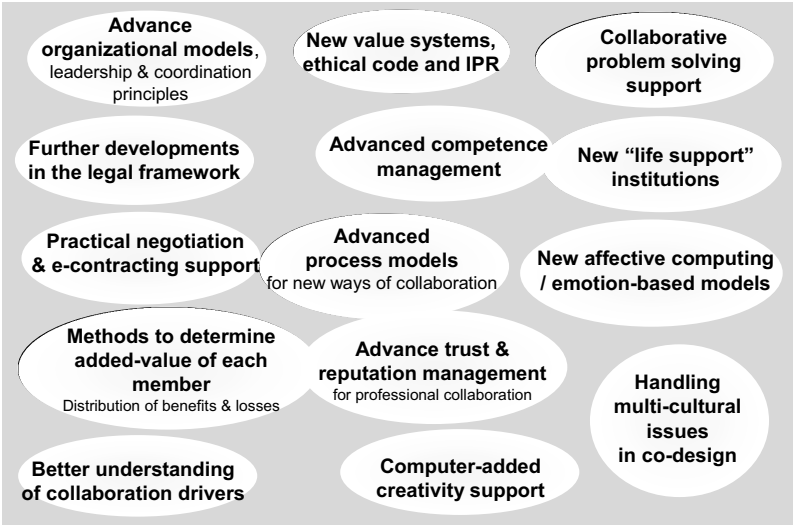


Figure 12. Examples of further research challenges in PVC

The introduction of a business dimension in these virtual communities although showing an interesting potential for knowledge workers, also raises additional challenges requiring further R&D. Examples of such challenges are shown in Fig. 12.

Another aspect requiring further work is the combination of PVCs and VBEs, i.e. PVCs composed of professionals working for the VBE organizations. This kind of hybrid structure requires specific models and support functionalities.

7. TOWARDS A REFERENCE MODEL

After an initial decade characterized by developments focused on solving particular problems and leading to fragmented solutions, in the last 5 years there is a growing awareness for the need of more holistic and sound approaches. The initial phase was also characterized by having different communities (e.g. engineering or management) addressing similar problems but with little or no interaction. Understanding that collaborative networks require contributions from multiple "adjacent" disciplines and a more structured theoretical foundation is leading to the consolidation of the area as a new discipline (Camarinha-Matos, Afsarmanesh, 2005). Some illustrative elements of this trend are shown in Fig. 13.

A major necessity is the elaboration of a reference model that could provide a general basis for understanding the significant concepts, entities, and relationships of some domain, and therefore a "foundation" for the area.

Modeling complex systems such as Collaborative Networks requires a proper framework to capture their complexity. For this purpose, ECOLEAD introduced the ARCON modeling framework (Camarinha-Matos, Afsarmanesh, 2007a, 2008). ARCON includes three perspectives: 1) Life cycle, 2) Environment characteristics, and 3) Modeling intent (Fig. 14).

The first defined perspective addresses the timing cycle of different CN life stages. This perspective captures the evolution of CNs and the diversity during their entire life cycle, represented by the vertical axis, labeled as "Life cycle stages".

The second defined perspective focuses on capturing the CN environment characteristics, represented by the horizontal axis, labeled as "Environment characteristics". This perspective further includes two subspaces (points of view) that comprehensively cover, the internal elements characteristics (labeled "Endogenous Elements") of CNs, as well as the external interactions characteristics (labeled "Exogenous Interactions") that address the logical surrounding of the CNs. For the endogenous elements perspective the following sub-dimensions are considered: Structural, Componential, Functional, and Behavioral. Under Endogenous Interactions the following sub-dimensions are included: Market, Support, Societal, and Constituency.

The third defined perspective for ARCON reference modeling is related to the different intents for the modeling of CN features, represented by the diagonal axis, labeled as "modeling intents". This perspective addresses the three possible modeling stages for CN elements, from the general representation, to the specific models (e.g. using a specific modeling approach or theory), and finally to the detailed specification of the implementation architecture for CN element.

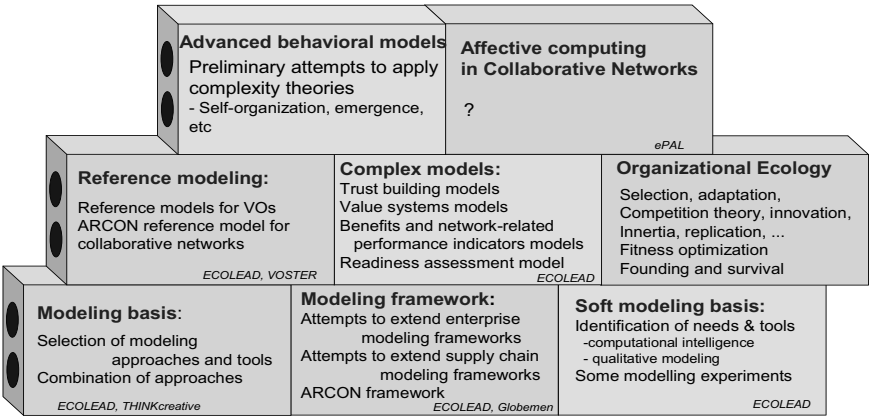


Figure 13. Progress on a theoretical foundation for CNs

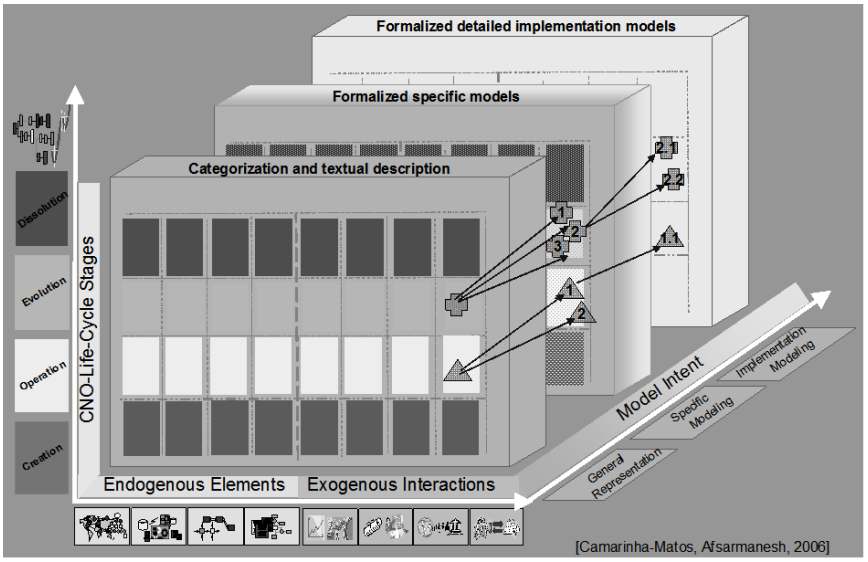
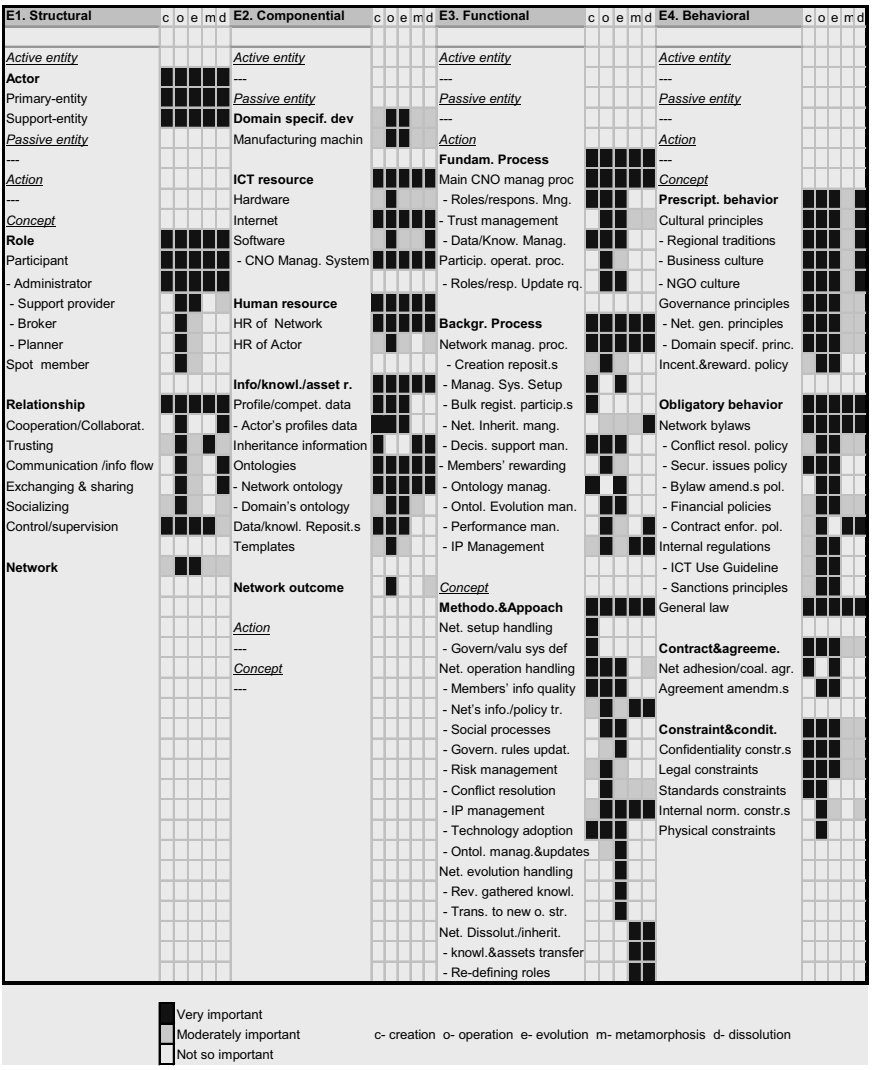


Figure 14. ARCON modeling framework

Using this framework, ECOLEAD also made a first attempt to collect and organize the most common general concepts under the endogenous elements and exogenous interactions perspectives, as briefly summarized in Fig. 15 and Fig. 16.

The framework was first applied to the CNO cases studied in ECOLEAD, namely VBEs, VOs, and PVCs. An attempt to generalize from these cases was then made, trying to identify a common set of concepts and entities, which were discussed with a wide group of experts from different fields. Nevertheless it is clear that it is not a finished job but rather a starting basis.



A textual description is also provided for each concept. Example:

- Broker — Role played by an actor when engaged in identifying and acquiring collaboration opportunities (business opportunities or others), by marketing CNO competencies and assets and negotiating with (potential) customers. Also responsible for interacting with (potential) customers, on behalf of the CNO, during the early phases of response to these opportunities. In some cases there is also the possibility of this opportunity brokerage role being played by an outside entity, as a service to the CNO.

For a complete description see (Camarinha-Matos, Afsarmanesh, 2008).

Figure 15. Contribution to a reference model – endogenous perspective

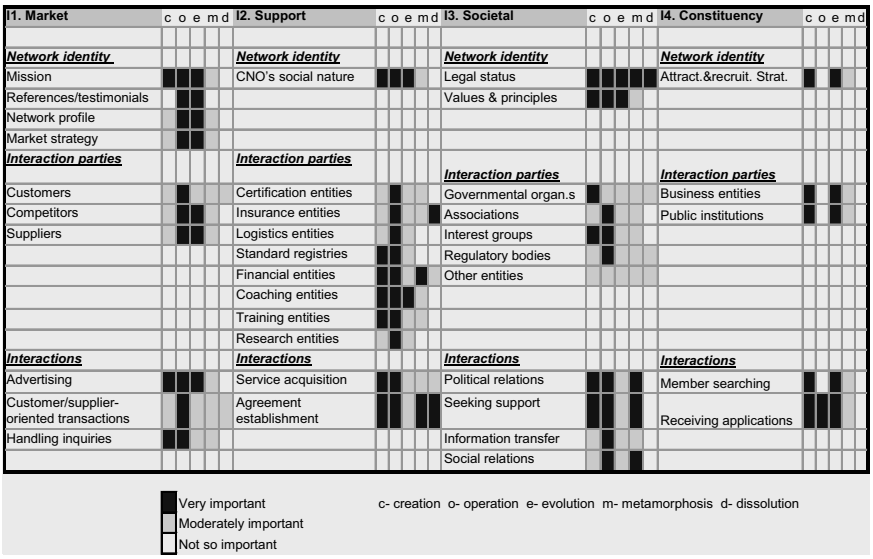


Figure 16. Contribution to a reference model – exogenous interactions perspective

Promising new directions, from a theoretical foundation perspective, are now being explored by different initiatives such as advanced behavioral models, including principles of emergence and self-organization, affective computing in collaborative networks, etc.

The ideas of Organizational Ecology (Hannan, Freeman, 1977), originated in the late 1970s are now being tried in the area of collaborative networks, e.g. to understand the emergence and survival of new organizational forms (Campos, 2007). Organizational Ecology combines the fields of sociology, ecology and organizational theories to provide a new description of the phenomena linking organizations and the environment.

8. EMERGING COLLABORATIVE FORMS

Currently the Collaborative Networks paradigm is spreading to new sectors and application cases. Some examples include:

1. Joint resource management (e.g. grid / dispersed manufacturing networks, computer grid).
2. Collaborative virtual lab (involving also remote access to lab resources).
3. Inter-modal collaboration (e.g. integrated transportation systems).
4. Collaborative e-government / network of governmental organizations.
5. Energy networks management (involving a network of producers, transporters, regulators, and even costumers with micro-production capability).
6. (Occasional) crisis management (e.g. rescue network in case of a major incident).
7. Customers involvement networks (kind of living lab).
8. Virtual institutes (e.g. a network of universities offering a joint e-learning programme).
9. Permanent crisis / social care (e.g. supporting homeless).
10. Collaborative gaming.
11. Collaborative innovation.
12. Context awareness service provision (i.e. providing services offered by different providers and that depend on the context, e.g. location of a mobile customer).
13. Machine and sensor networks (e.g. networks of robots).

Some of these cases pose new challenges and are likely to originate new classes of collaborative networks.

One interesting example is the customer involvement in innovation co-creation networks (Berger et al. 2005), (Hippel, 2002). The challenge here is to enable *collaborative innovation* involving a network of SMEs (manufacturers, designers, etc.), interfacing different entities and customers. Unlike previous works focused on interactions between one company and its customers, it is necessary to address the much more challenging scope of customer involved in networked collaboration and co-innovation, as shown in Fig. 17.

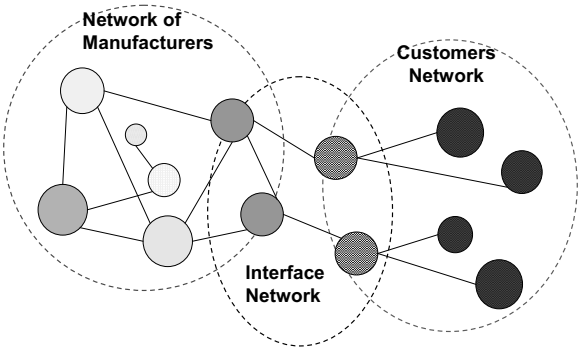


Figure 17. Customers' involvement in a CN

A great potential for innovation in collaborative networks comes thus from two different directions: 1) The application of the paradigm to new domains and scenarios, and 2) The exploration of new theories and approaches originated in different disciplines that can contribute with new insights to better understand and manage these complex systems.

9. CONCLUSIONS

The discipline of collaborative networks and particularly the collaborative networked organizations are going through an expansion and consolidation process as confirmed by the large amount of conceptual results, methodologies, support tools, and developed pilot demonstrations and applications during the last years.

Hand in hand with this progress, and especially as a result of the enlarging application base, new research challenges are being identified. Collaborative networks are nowadays applied in a large variety of sectors, including industrial manufacturing, services, logistics and transportation, energy management, education, agribusiness, government, research, elderly care, etc. The paradigm is becoming a pervasive phenomenon with a great potential. Further research and development shall materialize this potential.

On the theoretical foundation side, and complementing the first attempts to establish reference models, new approaches and theories originated in different fields are being adapted and extended to support a consolidation of this new discipline.

9.1. Acknowledgments

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